

# MRI-1 Ventilator

## Instruction Manual

***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 it 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, Inc.**

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## **STATEMENT OF WARRANTY**

IF THIS INSTRUMENT FAILS WITHIN A PERIOD OF ONE YEAR FROM THE DATE OF DELIVERY OR INSTALLATION, CWE, INC. WILL, AT ITS OPTION, REPAIR OR REPLACE IT FREE OF CHARGE. THIS WARRANTY EXCLUDES DAMAGE INCURRED THROUGH MISUSE OR ACCIDENT. CWE, INC. DOES NOT ASSUME ANY LIABILITY FOR ANY CONSEQUENTIAL DAMAGES RESULTING FROM THE USE OF THIS INSTRUMENT.

DEFECTIVE UNITS SHOULD BE RETURNED TO THE FACTORY ALONG WITH A NOTE DESCRIBING THE NATURE OF THE FAULT. THIS WARRANTY IS APPLICABLE TO THE ORIGINAL PURCHASER OF THE INSTRUMENT ONLY, AND IS NOT TRANSFERABLE.

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Out of warranty or damaged instruments may be returned to the factory freight prepaid for service at prevailing rates. Upon request, a written or verbal quotation for such service will be issued after examination of the unit but prior to commencing repairs or service. Address requests for service or technical information to:

CWE, Incorporated  
Technical Support  
25 St.Paul's Road  
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## **LIFE SUPPORT POLICY**

Instruments manufactured by CWE, Incorporated are not authorized for use as critical components in human life support devices or systems. "Life support devices or systems", as used herein, are devices or systems whose failure to perform, whether through misuse, failure, or proper operation, can reasonably be expected to result in significant injury to the operator or subject persons.

**TABLE OF CONTENTS**

1.0 INTRODUCTION.....	4
2.0 VENTILATOR CONNECTIONS AND SETUP .....	5
3.0 VENTILATOR SETTINGS.....	7
4.0 HOLD AND MANUAL SWITCHES .....	8
5.0 INDICATOR LIGHTS.....	8
6.0 SYNC OUT JACK (REAR PANEL).....	9
7.0 RS232 OUTPUT JACK (REAR PANEL).....	9
8.0 EXTERNAL VALVE JACK (REAR PANEL) .....	9
9.0 DATA INTERFACE (REAR PANEL).....	10
10.0 PORT CONNECTIONS (FRONT PANEL).....	11
11.0 PORT CONNECTIONS (REAR PANEL) .....	11
12.0 USING ANESTHESIA WITH THE MRI-1 .....	12
13.0 USING EXTERNAL VALVE ASSEMBLIES .....	13
14.0 SPECIFICATIONS .....	14
15.0 ORDERING INFORMATION .....	15
APPENDIX 1: TIDAL VOLUME VS. BODY WEIGHT CHARTS .....	16
APPENDIX 2: TIDAL VOLUME TABLES .....	17
APPENDIX 3: TYPICAL VENTILATOR SETTINGS FOR RODENTS.....	19

## 1.0 INTRODUCTION

The MRI-1 Ventilator is a small animal ventilator specifically designed for use in high magnetic field environments. The ventilator consists of a controller and a set of miniature non-metallic pneumatic valves. These remote valves perform respiratory gas switching close to the animal (even inside the magnet bore). This alleviates the dead-space and compliance issues associated with long tubing runs from the ventilator to the animal. The MRI-1 is intended for rodent size animals.

This ventilator operates on the *flow-time* principle; a constant airflow is gated into the animal for a set time, thus producing a known tidal volume. This approach permits great flexibility, since respiratory rate (RR), inspiratory time ( $T_I$ ), and airflow are independently set, and can all be adjusted while the ventilator is running. All parameters are set from the front panel, and are displayed on an LCD display along with the computed tidal volume ( $V_T$ ) and minute ventilation (MV).

A built-in air pump provides inspiratory airflow. An external source of compressed gas (typically air or helium) is required for pneumatic valve actuation. The MRI-1 has a built-in digital interface for controlling the ventilator from an external computer. A serial output provides current ventilator settings for remote monitoring or data collection.

Besides the standard pneumatic valves, the MRI-1 can be used with any of the CTP-VA series external valve assemblies for non-magnetic environments. These valve assemblies are available for a range of animals (see Ordering Information).

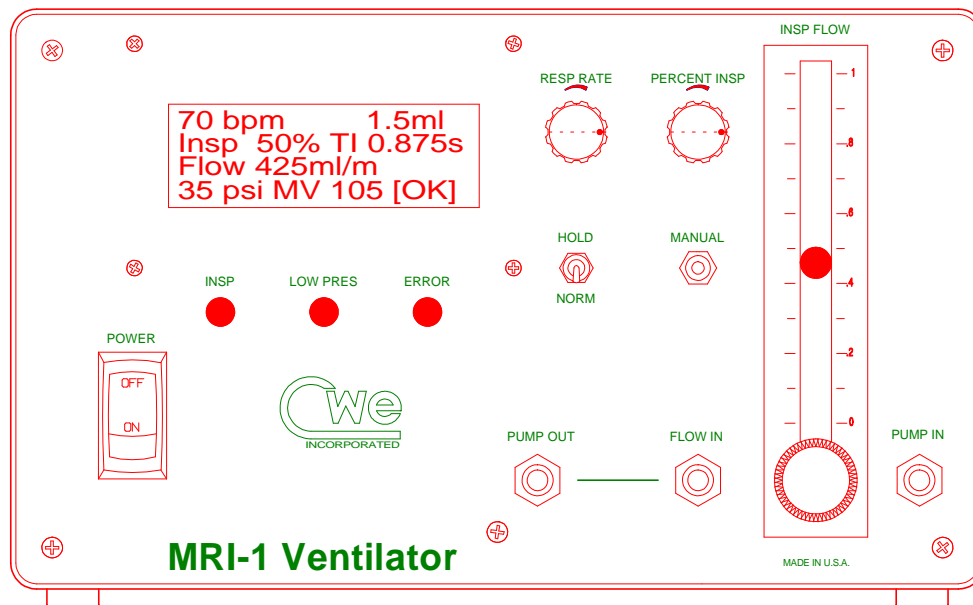


Figure 1: Model MRI-1 Front Panel

## 2.0 VENTILATOR CONNECTIONS AND SETUP

### **Tubing Connections --- main unit to remote valves:**

Setting up the MRI-1 is straightforward (see *Figure 3: Connection Diagram*). Two lengths of tubing connect the control unit to the remote valves; one provides the inspiratory flow to the animal, and the other provides the compressed air for valve actuation. The flow tubing can be 1/8" (3.1mm) ID Tygon® or other standard flexible laboratory tubing. The valve actuation tubing should be high-pressure, semi-rigid tubing with an ID of 0.058" (1.5mm).

**Valve actuation tubing** --- Connect between the **VALVE ACTUATION** port (rear panel) and the top port on each of the two remote valves, using a "T" adapter. Use tubing clamps on these connections.

**Inspiratory flow tubing** --- Connect between the **FLOW OUT** port (rear panel) and the **Com** (common) port on the remote **INSP** valve.

### **Tubing Connections --- remote valves to animal:**

Two short lengths of tubing and a "Y" connector are required. To reduce compression effects, these tubes should be as short as is convenient, but their length does not affect dead-space, since flow is unidirectional. The only dead-space is the volume from the distal end of the "Y" connector to the tracheal tube. This tubing should be 1/8" (3.1mm) inside diameter Tygon® or similar for rats and larger rodents. For mice, use 1/16" (1.6mm) I.D. tubing and a correspondingly small "Y" fitting.

**Inspiration tubing** --- Connect between the "I" port on the **INSP** valve and the "Y" connector.

**Expiration tubing** --- Connect between the "E" port on the **Exp** valve and the "Y" connector.

**Endotracheal tube connections** --- The distal end of the "Y" connector must be securely connected to the endotracheal tube. The form of this connection will vary depending on the tracheal tube, but in any case it must be leak-proof. A number of small adapter fittings are included in the Accessory Kit, which should be of help in establishing a good tracheal tube connection.

### **Other tubing connections:**

If desired, the **EXP AIR** port on the **EXP** valve can be used to collect or monitor expired air from the animal. Otherwise, leave this unconnected. The excess inspiratory airflow emerges from the **INSP VENT** port on the **INSP** valve, which can be left unconnected.

To use room air for ventilation, connect a short length of tubing between the **PUMP OUT** and **FLOW IN** ports on the front panel of the control unit. If a pressurized (5-20 psi) anaesthetic gas is being used, connect it to the **FLOW IN** port, and leave the **PUMP OUT** port unconnected.

# MRI-1 Ventilator Instruction Manual

p. 6

**NOTE:** If the internal air pump is being used, do not apply a pressure to the PUMP IN port. A collapsible bag with a gas mixture can, however, be connected to this port.

## Electrical Power Connection:

Be sure that the **LINE VOLTAGE SELECTOR** switch (rear panel) is set correctly. Plug the line cord into the receptacle on the rear panel, and plug the other end into a grounded power receptacle.

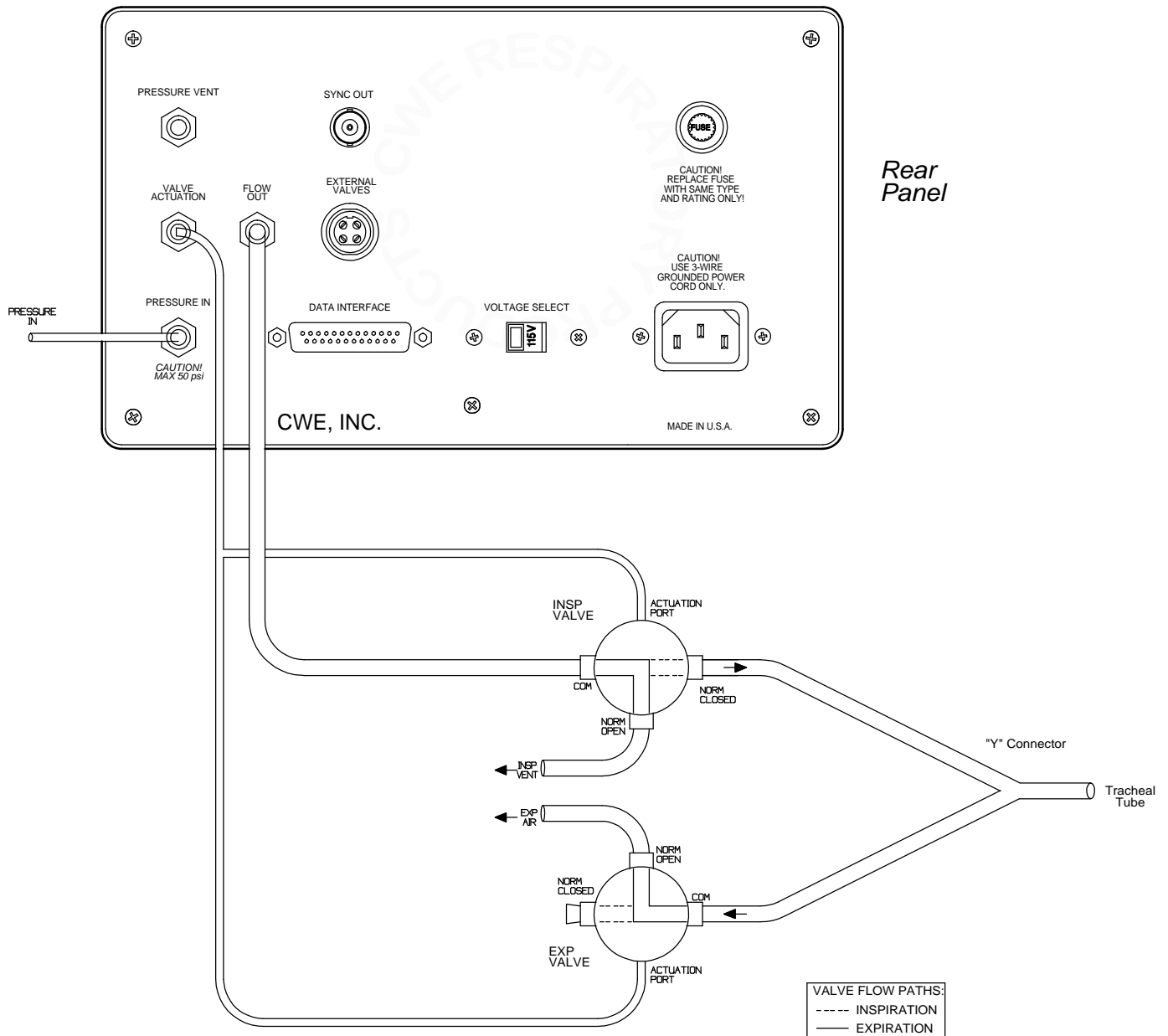


Figure 3: Remote valves tubing connection diagram

### 3.0 VENTILATOR SETTINGS

#### Respiratory rate and tidal volume:

The basic respiratory parameters of any ventilator are *tidal volume* ( $V_T$ ) and *respiratory rate* (RR). Respiratory rate is set directly using the **RESP RATE** knob, and reading it out on the top line of the LCD display.

Tidal volume in a flow-time ventilator has two components which are adjusted independently: flow rate and inspiratory time ( $T_I$ ). On the MRI-1,  $T_I$  is always fixed as a fraction (the I/E ratio) of the total respiratory cycle time (inspiration + expiration), and thus  $T_I$  will automatically change when the respiratory rate is changed. The I/E ratio is set using the **% INSP** knob, and this setting is shown on the second line of the LCD display. This ratio can be set anywhere in the range of 10 – 90% of the total cycle time, but is usually set to around 50%. The resultant  $T_I$  is shown on the LCD display.

The second component of tidal volume is inspiratory flow rate. The higher this flow, the larger the volume that will be delivered for any given  $T_I$ . The adjustment knob at the base of the front-panel flowmeter is used to set this flow. An internal mass flowmeter measures this airflow, and it is reported on the third line of the LCD display. The resultant  $V_T$  is shown on the first line of the LCD display.

To summarize, the respiratory rate is set directly. Next, set the **% INSP** to 50% or whatever is desired. Finally, adjust the flow rate until the desired tidal volume is shown.

#### Minute ventilation:

Minute ventilation (MV) is the total volume delivered to the animal in one minute. This is simply the product of tidal volume and respiratory rate. MV is reported on the fourth line of the LCD display in milliliters.

Note that MV does not increase simply by increasing respiratory rate. This may seem counterintuitive, but on reflection it is easy to see why this is the case. With a fixed I/E ratio, the inspiratory time always reflects a fixed proportion of the total cycle time ( $1/\text{rate}$ ). For example, at a rate of 60 bpm, exactly 1.0 second is available for the total cycle time. If the I/E ratio is 50%, then 0.5 second is the inspiratory time. If the rate is changed to 120 bpm, the  $T_I$  will automatically drop to 0.25 second. Although the respiratory rate has doubled, each inspiration is only half of what it was before. Thus, the sum of all the inspired volumes remains the same.

This scheme will be seen to provide extraordinary control over the mechanics and timing of respiration. Once set up for a given  $V_T$ , it is a simple matter to increase or decrease it by changing the flow rate or I/E ratio.

## 4.0 HOLD AND MANUAL SWITCHES

### **HOLD switch:**

When switched to **HOLD**, the ventilator is put into a constant expiration mode. To resume normal ventilation, switch to the **NORM** position. This function is useful in cases where it is desirable to temporarily suspend respiratory movement, e.g., during imaging.

### **MAN switch:**

Pressing this pushbutton causes inspiration to occur, regardless of the state of the ventilator. Inspiration persists as long as the pushbutton is depressed. This function is useful for generating a sigh, or temporary hyperinflation.

***NOTE: Both of these functions can be operated by remote control using the DATA INTERFACE on the rear panel. See the Data Interface section below for details.***

## 5.0 INDICATOR LIGHTS

### **INSPIRATION:**

This green LED turns on during inspiration, and is off during expiration.

### **LOW PRESSURE:**

This LED lights when the valve actuation pressure is below 20 psi (1.4 bar). If this actuation pressure is too low, the valves will operate sluggishly or not at all. Normally, the pressure at the Pressure In port should be in the range 25 – 50 psi (1.7 – 3.4 bar).

### **ERROR:**

This LED lights when the ventilator detects an error condition, such as when the actuation pressure is too low.



## 6.0 SYNC OUT JACK (rear panel)

This BNC jack provides a TTL-compatible logic signal corresponding to the current phase of ventilation. Inspiration is logic high (+5V) and expiration is logic low (0V). This signal is used for synchronizing external equipment to the animal's respiratory phase.

## 7.0 RS232 OUTPUT JACK (rear panel)

This jack provides a standardized RS232 serial output that can be used for remote monitoring or data collection. The serial protocol is very generic: 9600,N,8,1. The data is output as straight ASCII text in the following format:

```
rrr,vvv<CR><LF>
```

where rrr = respiratory rate in bpm, vvv = tidal volume in ml,

<CR> = carriage return (ASCII 13), and <LF> = line feed (ASCII 10).

This data is sent every ten seconds. The mating connector is a 3.5mm mini 3-conductor phone plug. A complete serial cable for connection to a PC is wired as follows:

Phone plug	DB9S
=====	=====
TIP	pin 2
SHELL	pin 5

## 8.0 EXTERNAL VALVE JACK (rear panel)

This 4-pin jack is used to connect an **EXTERNAL VALVE ASSEMBLY** to the ventilator for use in non-magnetic environments. Any of the CTP-VA series valves may be used, which are available in sizes suitable for mice to dogs. In addition, multiple CTP-VA-1 Valve Assemblies (rodent size) can be operated from one MRI-1 controller. This requires the use of one MVA-4 Multi-valve Adapter, and one external flowmeter for each animal (see Ordering Information). When using multiple external valve assemblies, the automatic tidal volume calculation feature of the MRI-1 will not be operative, since the internal flow monitor will not be able to measure the actual airflow to each animal (other than the one receiving its **Flow In** source directly from the MRI-1).

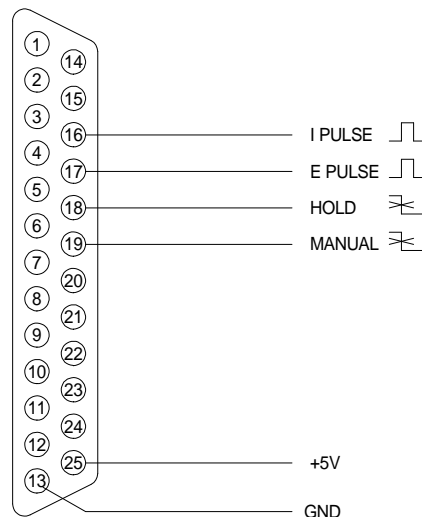
## **9.0 DATA INTERFACE (rear panel)**

This DB-25 connector provides access to a number of monitoring outputs and control inputs (see *Figure 2*). Using these inputs, it is possible to control the ventilator from an external device such as a computer. All the logic inputs are TTL-compatible. The output signals have the same properties as described elsewhere in this manual. The correct mating connector is a DB-25 male connector.

### **Standard SAR-830 DATA INTERFACE connections:**

Pin 16	Inspiratory Pulse, 1mS pulse at start of inspiration
Pin 17	Expiratory Pulse, 1mS pulse at start of expiration
Pin 18	HOLD Input (NORM=HIGH, HOLD=LOW)
Pin 19	MAN Input (NORM=HIGH, MANUAL INSP=LOW)
Pin 13	Ground
Pin 25	+5V

## **MRI-1 DATA PORT**



Required mating connector is  
DB25P male plug

*Figure 2: MRI-1 Data Port connections*

## 10.0 PORT CONNECTIONS (Front Panel)

### PUMP IN:

This is the inlet port for the internal air pump. Normally, room air will be drawn in through this port. Other gasses can be used, but pressure sources should not be directly connected here. If gas mixtures are being used, use a flexible gas collection bag as a collapsible reservoir.

### PUMP OUT:

This is the outlet port for the internal air pump. To use the internal air pump as the ventilator pressure source, connect this port to the adjacent **FLOW IN** port.

### FLOW IN:

This is the main inlet for the ventilator's inspiratory flow. The compressed air (or other gas) introduced here is the source of inspiratory airflow. This pressure should be within the range 3 - 20psi. The output of most anesthesia machines can be connected to this port.

## 11.0 PORT CONNECTIONS (Rear Panel)

### PRESSURE IN:

This is the compressed gas inlet for use in remote pneumatic valve actuation. Normally, compressed air at around 25 - 50 psi (1.7 - 3.4 bar) is used. To slightly increase the speed of the remote valves, helium can be used instead of air. It is recommended that tubing clamps be used on this connection.

***NOTE: Do not exceed 90psi (6.1bar) on this port. Pressures higher than this will cause internal tubing connections to blow off.***

### VALVE ACTUATION:

This port is connected using flexible tubing to the actuation (top) ports on the two remote pneumatic valves. It is recommended that tubing clamps be used on this connection.

### PRESSURE VENT:

This port vents the pressure from the remote valves when they are deactivated. Normally no connection is required to this port.

## FLOW OUT:

The constant inspiratory airflow is delivered to the remote valves from this port. This should be connected to the **FLOW IN** port of the remote **INSP VALVE** using flexible tubing.

## 12.0 USING ANESTHESIA WITH THE MRI-1

The MRI-1 ventilator is compatible with most forms of inhalational anesthesia. If an anesthesia machine is available, its pressurized output can be connected directly to the **FLOW IN** port on the MRI-1.

CWE, Inc. can also provide complete anesthesia setups. The simplest Isoflurane or Halothane setup consists of a vaporizer, connected as follows:

- ❶ Connect the inlet of the vaporizer to the **FLOW OUT** port on the MRI-1 rear panel. Connect the tubing supplying inspiratory airflow to the remote valve set (1/8" ID Tygon) to the outlet of the vaporizer.
- ❷ If using room air as the breathing gas, be sure the short tubing jumper between the **PUMP OUT** port and **FLOW IN** port is in place. This allows the internal air pump to supply the compressed breathing air.
- ❸ If using oxygen, connect a rubber breathing bag to the **PUMP IN** port. Keep this flexible reservoir bag filled with oxygen as needed. This allows the air pump to draw gas from the bag.

***CAUTION! Do not connect pressurized gas directly to the PUMP IN port! This will damage the internal air pump.***

These components are available as an Anesthesia Kit (see *Ordering Information*).

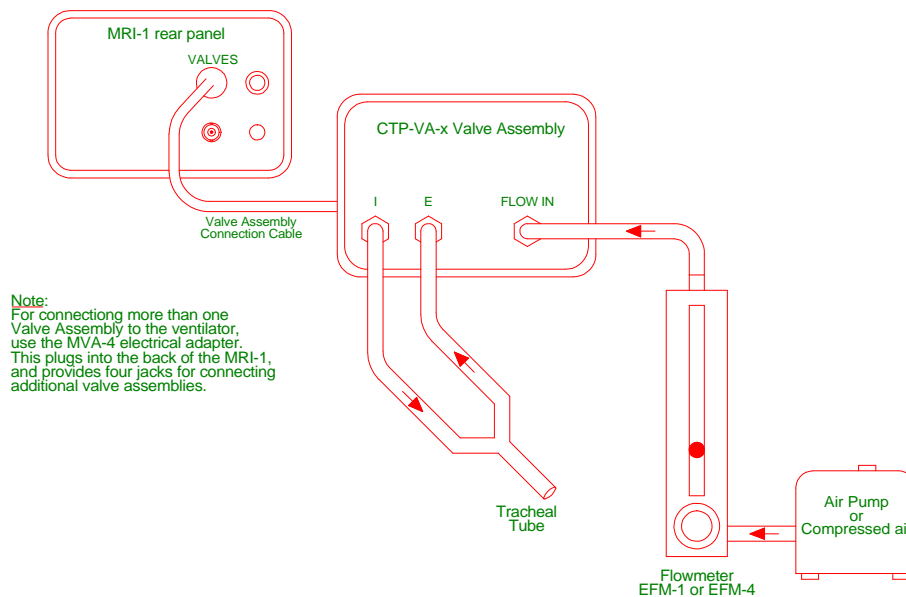
## 13.0 USING EXTERNAL VALVE ASSEMBLIES

The MRI-1 comes equipped with a set of non-metallic, pneumatically-actuated valves. This configuration is designed for use in the intense magnetic environment associated with MRI equipment. However, the ventilator can also be used with any of the CTP-VA series External Valve Assemblies available from CWE, Inc. The valve assemblies use conventional solenoid valves, and are thus not suitable for the MRI environment.

For ventilating one animal, you need a CTP-VA series valve assembly, a flowmeter/regulator, and an air source (see *Figure 3*). The following table shows which valve assemblies and flowmeters to use for various animals:

Valve Assembly	Flowmeter	Animal
CTP-VA-1	EFM-1-1	Rat, Guinea pig
CTP-VA-3	EFM-1-2.5	Cat, Rabbit
CTP-VA-4	EFM-1-20	Dog, Goat

It is also possible to ventilate up to four rodents simultaneously with just one MRI-1 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.



### External Valve Assembly Connections

*Figure 3: Using an External Valve Assembly with the MRI-1*

## 14.0 SPECIFICATIONS

Respiratory rate range .....	5 - 200 breaths/min
Inspiratory flow range .....	60 - 1000ml/min
Inspiration/Expiration (I/E ratio) range.....	10 - 90%
Tidal volume range (see Note 1).....	0.1 - 100ml
Manual control functions .....	HOLD (suspends inspiration), MAN (manual inflation)
LCD panel.....	4 lines x 20 chars, backlit
Indicator lights .....	INSPIRATION, LOW PRES WARNING, ERROR
Internal airpump capacity.....	1 lpm
Pneumatic valve switching speed (air actuation) .....	< 75mS
Pneumatic valve switching speed (Helium actuation) .....	< 55mS
Pneumatic valve actuation pressure .....	3 - 5 bar
Pneumatic valve flow orifices.....	0.080 in. (2.0mm)
Pneumatic valve materials .	PTFE body, plastic fasteners, one non-ferrous coil spring
Dimensions, main unit .....	9W x 5.5H x 9D in. (23 x 14 x 23cm)
Dimensions, pneumatic valve (each, of two) .....	1.0 dia x 1.8 long, in. (47 x 25mm)
Port connections, respiratory and pressure functions ..	0.125" (3mm) ID Tygon tubing
SYNC OUT connector.....	BNC
Data Port connector.....	DB-25S
Power requirements.....	120/240V (switchable), 100VA

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

# MRI-1 Ventilator Instruction Manual

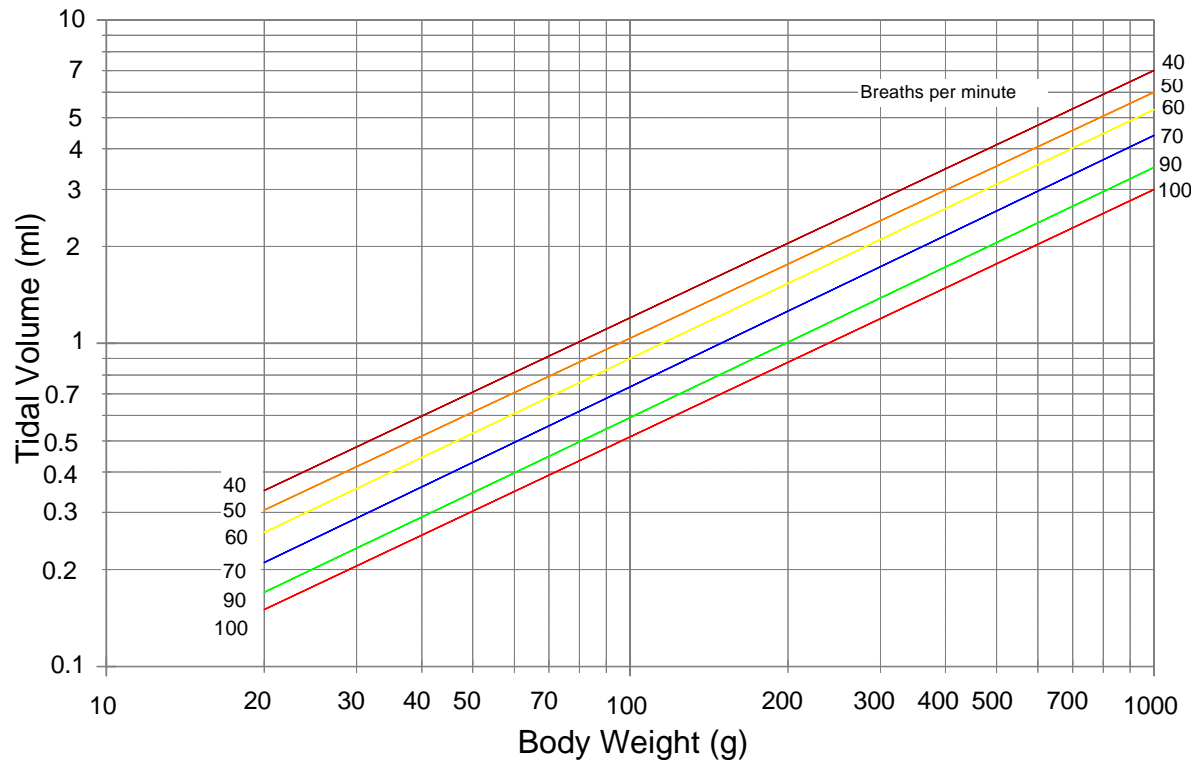
## p. 15

### 15.0 ORDERING INFORMATION

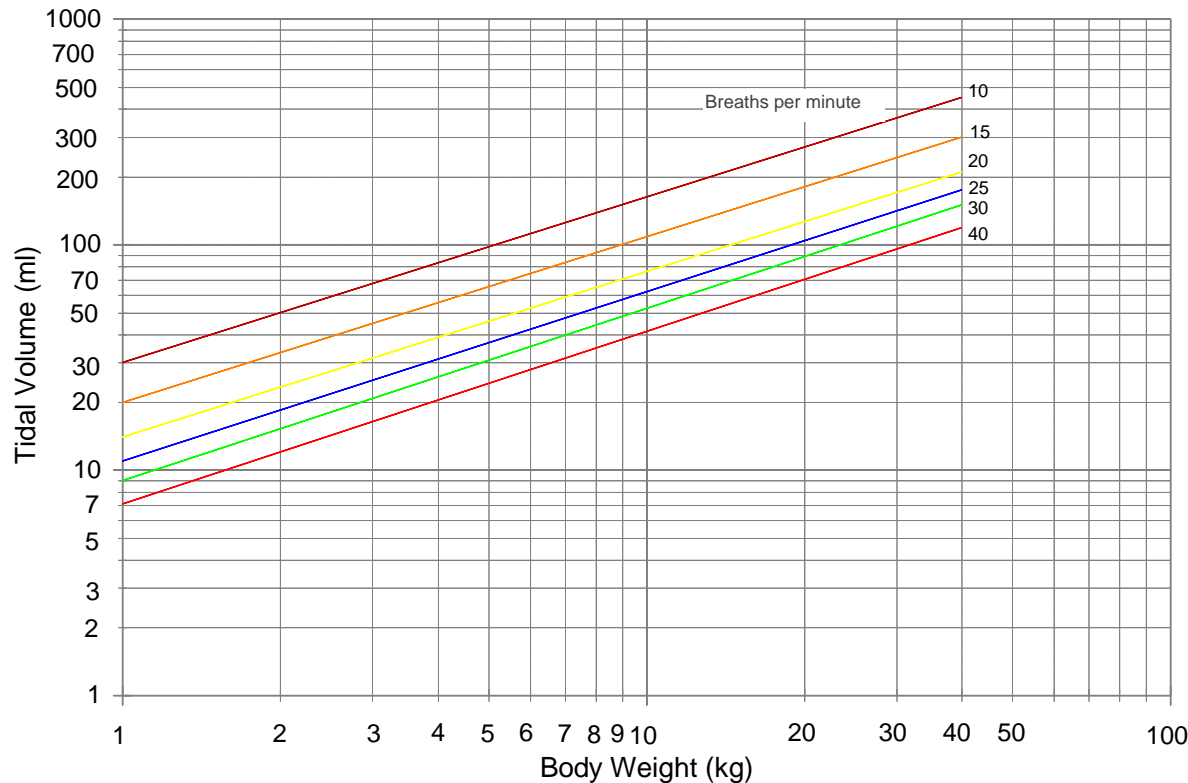
PART N°	MODEL	DESCRIPTION
12-07000	MRI-1	Ventilator with remote pneumatic valve set, 115/230V operation,
12-07100	Pneumatic Valves	Non-metallic pneumatic valve set with tubing and fittings
12-04000	CTP-VA-1	Solenoid Valve Assembly, mouse to Guinea pig size
12-05000	CTP-VA-3	Solenoid Valve Assembly, cat to small dog size
12-06000	CTP-VA-4	Solenoid Valve Assembly, dog to goat 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: 1, 2.5, 5, 10, or 20 l/min
12-10021	EFM-4	Flowmeter/regulator manifold w/ 4 flowmeters, with stand, specify range
12-10030	OPTION 020	External Air Pump, 0-1.5l/min range (pumps room air only: no inlet port)
12-10031	OPTION 022	External Air Pump, 0-4l/min range (pumps room air only: no inlet port)
11-10000	CAPSTAR-100	End-tidal CO <sub>2</sub> Analyzer, complete with accessory pack, 115/230V operation
13-12000	Halothane kit	Halothane vaporizer, flowmeter, tubing & fittings
13-13000	Isoflurane kit	Isoflurane vaporizer, flowmeter, tubing & fittings
13-10110	1 liter bag	Rubber rebreathing bag, 1 liter
13-10120	3 liter bag	Rubber rebreathing bag, 3 liter

APPENDIX 1: TIDAL VOLUME VS. BODY WEIGHT CHARTS

Tidal Volume Chart



Tidal Volume Chart





# MRI-1 Ventilator Instruction Manual

p. 17

## APPENDIX 2: TIDAL VOLUME TABLES

I Time (sec)	Typ Rate	Flow Rate (cc/min)									
		100	200	300	400	500	600	700	800	900	1000
0.1	300	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.5	1.7
0.2	150	0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3
0.3	100	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0.4	75	0.7	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7
0.5	60	0.8	1.7	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3
0.6	50	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.7	43	1.2	2.3	3.5	4.7	5.8	7.0	8.2	9.3	10.5	11.7
0.8	38	1.3	2.7	4.0	5.3	6.7	8.0	9.3	10.7	12.0	13.3
0.9	33	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0
1.0	30	1.7	3.3	5.0	6.7	8.3	10.0	11.7	13.3	15.0	16.7
1.1	27	1.8	3.7	5.5	7.3	9.2	11.0	12.8	14.7	16.5	18.3
1.2	25	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0
1.3	23	2.2	4.3	6.5	8.7	10.8	13.0	15.2	17.3	19.5	21.7
1.4	21	2.3	4.7	7.0	9.3	11.7	14.0	16.3	18.7	21.0	23.3
1.5	20	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
1.6	19	2.7	5.3	8.0	10.7	13.3	16.0	18.7	21.3	24.0	26.7
1.7	18	2.8	5.7	8.5	11.3	14.2	17.0	19.8	22.7	25.5	28.3
1.8	17	3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0	30.0
1.9	16	3.2	6.3	9.5	12.7	15.8	19.0	22.2	25.3	28.5	31.7
2.0	15	3.3	6.7	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3
2.1	14	3.5	7.0	10.5	14.0	17.5	21.0	24.5	28.0	31.5	35.0
2.2	14	3.7	7.3	11.0	14.7	18.3	22.0	25.7	29.3	33.0	36.7
2.3	13	3.8	7.7	11.5	15.3	19.2	23.0	26.8	30.7	34.5	38.3
2.4	12	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0
2.5	12	4.2	8.3	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7
2.6	12	4.3	8.7	13.0	17.3	21.7	26.0	30.3	34.7	39.0	43.3
2.7	11	4.5	9.0	13.5	18.0	22.5	27.0	31.5	36.0	40.5	45.0
2.8	11	4.7	9.3	14.0	18.7	23.3	28.0	32.7	37.3	42.0	46.7
2.9	10	4.8	9.7	14.5	19.3	24.2	29.0	33.8	38.7	43.5	48.3
3.0	10	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
3.1	10	5.2	10.3	15.5	20.7	25.8	31.0	36.2	41.3	46.5	51.7
3.2	9	5.3	10.7	16.0	21.3	26.7	32.0	37.3	42.7	48.0	53.3
3.3	9	5.5	11.0	16.5	22.0	27.5	33.0	38.5	44.0	49.5	55.0
3.4	9	5.7	11.3	17.0	22.7	28.3	34.0	39.7	45.3	51.0	56.7
3.5	9	5.8	11.7	17.5	23.3	29.2	35.0	40.8	46.7	52.5	58.3
3.6	8	6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0	60.0
3.7	8	6.2	12.3	18.5	24.7	30.8	37.0	43.2	49.3	55.5	61.7
3.8	8	6.3	12.7	19.0	25.3	31.7	38.0	44.3	50.7	57.0	63.3
3.9	8	6.5	13.0	19.5	26.0	32.5	39.0	45.5	52.0	58.5	65.0
4.0	7	6.7	13.3	20.0	26.7	33.3	40.0	46.7	53.3	60.0	66.7
4.1	7	6.8	13.7	20.5	27.3	34.2	41.0	47.8	54.7	61.5	68.3
4.2	7	7.0	14.0	21.0	28.0	35.0	42.0	49.0	56.0	63.0	70.0
4.3	7	7.2	14.3	21.5	28.7	35.8	43.0	50.2	57.3	64.5	71.7
4.4	7	7.3	14.7	22.0	29.3	36.7	44.0	51.3	58.7	66.0	73.3
4.5	7	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0
4.6	7	7.7	15.3	23.0	30.7	38.3	46.0	53.7	61.3	69.0	76.7
4.7	6	7.8	15.7	23.5	31.3	39.2	47.0	54.8	62.7	70.5	78.3
4.8	6	8.0	16.0	24.0	32.0	40.0	48.0	56.0	64.0	72.0	80.0
4.9	6	8.2	16.3	24.5	32.7	40.8	49.0	57.2	65.3	73.5	81.7
5.0	6	8.3	16.7	25.0	33.3	41.7	50.0	58.3	66.7	75.0	83.3

# MRI-1 Ventilator Instruction Manual

p. 18

## APPENDIX 2, cont'd: TIDAL VOLUME TABLES

Flow Rate (cc/min)

Time (sec)	Typ Rate	200	400	600	800	1000	1200	1400	1600	1800	2000
0.2	150	0.7	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7
0.4	75	1.3	2.7	4.0	5.3	6.7	8.0	9.3	10.7	12.0	13.3
0.6	50	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0
0.8	38	2.7	5.3	8.0	10.7	13.3	16.0	18.7	21.3	24.0	26.7
1.0	30	3.3	6.7	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3
1.2	25	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0
1.4	21	4.7	9.3	14.0	18.7	23.3	28.0	32.7	37.3	42.0	46.7
1.6	19	5.3	10.7	16.0	21.3	26.7	32.0	37.3	42.7	48.0	53.3
1.8	17	6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0	60.0
2.0	15	6.7	13.3	20.0	26.7	33.3	40.0	46.7	53.3	60.0	66.7
2.2	14	7.3	14.7	22.0	29.3	36.7	44.0	51.3	58.7	66.0	73.3
2.4	13	8.0	16.0	24.0	32.0	40.0	48.0	56.0	64.0	72.0	80.0
2.6	12	8.7	17.3	26.0	34.7	43.3	52.0	60.7	69.3	78.0	86.7
2.8	11	9.3	18.7	28.0	37.3	46.7	56.0	65.3	74.7	84.0	93.3
3.0	10	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
3.2	9	10.7	21.3	32.0	42.7	53.3	64.0	74.7	85.3	96.0	106.7
3.4	9	11.3	22.7	34.0	45.3	56.7	68.0	79.3	90.7	102.0	113.3
3.6	8	12.0	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108.0	120.0
3.8	8	12.7	25.3	38.0	50.7	63.3	76.0	88.7	101.3	114.0	126.7
4.0	7	13.3	26.7	40.0	53.3	66.7	80.0	93.3	106.7	120.0	133.3
4.2	7	14.0	28.0	42.0	56.0	70.0	84.0	98.0	112.0	126.0	140.0
4.4	7	14.7	29.3	44.0	58.7	73.3	88.0	102.7	117.3	132.0	146.7
4.6	7	15.3	30.7	46.0	61.3	76.7	92.0	107.3	122.7	138.0	153.3
4.8	6	16.0	32.0	48.0	64.0	80.0	96.0	112.0	128.0	144.0	160.0
5.0	6	16.7	33.3	50.0	66.7	83.3	100.0	116.7	133.3	150.0	166.7
5.2	6	17.3	34.7	52.0	69.3	86.7	104.0	121.3	138.7	156.0	173.3
5.4	6	18.0	36.0	54.0	72.0	90.0	108.0	126.0	144.0	162.0	180.0
5.6	5	18.7	37.3	56.0	74.7	93.3	112.0	130.7	149.3	168.0	186.7
5.8	5	19.3	38.7	58.0	77.3	96.7	116.0	135.3	154.7	174.0	193.3
6.0	5	20.0	40.0	60.0	80.0	100.0	120.0	140.0	160.0	180.0	200.0
6.2	5	20.7	41.3	62.0	82.7	103.3	124.0	144.7	165.3	186.0	206.7
6.4	5	21.3	42.7	64.0	85.3	106.7	128.0	149.3	170.7	192.0	213.3
6.6	5	22.0	44.0	66.0	88.0	110.0	132.0	154.0	176.0	198.0	220.0
6.8	4	22.7	45.3	68.0	90.7	113.3	136.0	158.7	181.3	204.0	226.7
7.0	4	23.3	46.7	70.0	93.3	116.7	140.0	163.3	186.7	210.0	233.3
7.2	4	24.0	48.0	72.0	96.0	120.0	144.0	168.0	192.0	216.0	240.0
7.4	4	24.7	49.3	74.0	98.7	123.3	148.0	172.7	197.3	222.0	246.7
7.6	4	25.3	50.7	76.0	101.3	126.7	152.0	177.3	202.7	228.0	253.3
7.8	4	26.0	52.0	78.0	104.0	130.0	156.0	182.0	208.0	234.0	260.0
8.0	4	26.7	53.3	80.0	106.7	133.3	160.0	186.7	213.3	240.0	266.7
8.2	4	27.3	54.7	82.0	109.3	136.7	164.0	191.3	218.7	246.0	273.3
8.4	4	28.0	56.0	84.0	112.0	140.0	168.0	196.0	224.0	252.0	280.0
8.6	3	28.7	57.3	86.0	114.7	143.3	172.0	200.7	229.3	258.0	286.7
8.8	3	29.3	58.7	88.0	117.3	146.7	176.0	205.3	234.7	264.0	293.3
9.0	3	30.0	60.0	90.0	120.0	150.0	180.0	210.0	240.0	270.0	300.0
9.2	3	30.7	61.3	92.0	122.7	153.3	184.0	214.7	245.3	276.0	306.7
9.4	3	31.3	62.7	94.0	125.3	156.7	188.0	219.3	250.7	282.0	313.3
9.6	3	32.0	64.0	96.0	128.0	160.0	192.0	224.0	256.0	288.0	320.0
9.8	3	32.7	65.3	98.0	130.7	163.3	196.0	228.7	261.3	294.0	326.7
10.0	3	33.3	66.7	100.0	133.3	166.7	200.0	233.3	266.7	300.0	333.3

### **APPENDIX 3: TYPICAL VENTILATOR SETTINGS FOR RODENTS**

<b>Body Weight (g)</b>	<b>Tidal Volume (ml)</b>	<b>Resp Rate (br/min)</b>	<b>Insp Flow (ml/min)</b>	<b>I/E Ratio (%)</b>
<b>30</b>	0.22	90	40	50
<b>50</b>	0.40	75	60	50
<b>100</b>	0.90	60	110	50
<b>200</b>	1.70	50	170	50
<b>300</b>	2.30	50	230	50
<b>500</b>	4.00	40	320	50

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.