



# In-service Manual

## TABLE OF CONTENTS

<b>HOW TO USE THIS MANUAL .....</b>	<b>.....</b>
<b>CHAPTER 1: OVERVIEW .....</b>	<b>.....</b>
<b>HFV WITH CV .....</b>	<b>3</b>
<b>LIFEPORT ADAPTER .....</b>	<b>4</b>
<b>CHAPTER 2: SETUP .....</b>	<b>.....</b>
<b>REAR PANEL CONNECTIONS .....</b>	<b>6</b>
<b>FRONT PANEL CONNECTIONS .....</b>	<b>7</b>
<b>PATIENT BOX CONNECTIONS.....</b>	<b>8</b>
<b>SETUP CAUTIONS .....</b>	<b>9</b>
<b>CHAPTER 3: VENTILATOR CONTROLS &amp; TEST PROCEDURE .....</b>	<b>.....</b>
<b>THE CONTROLS SECTION .....</b>	<b>11</b>
<b>PERFORMING A TEST .....</b>	<b>12</b>
<b>A FAILED TEST .....</b>	<b>13</b>
<b>CHAPTER 4: PRESSURE MONITORING.....</b>	<b>.....</b>
<b>MONITOR DISPLAYS .....</b>	<b>15</b>
<b>PRESSING ENTER BUTTON .....</b>	<b>16</b>
<b>PURGE PAUSES .....</b>	<b>17</b>
<b>CHAPTER 5: HUMIDIFIER .....</b>	<b>.....</b>
<b>GAS FLOW THROUGH HUMIDIFIER .....</b>	<b>19</b>
<b>STARTING THE HUMIDIFIER .....</b>	<b>21</b>
<b>CHANGING THE CIRCUIT .....</b>	<b>22</b>
<b>CIRCUIT CHANGE PREPARATIONS .....</b>	<b>.....</b>
<b>CHECKLIST .....</b>	<b>.....</b>
<b>FRONT PANEL DUTIES .....</b>	<b>.....</b>
<b>PATIENT BOX DUTIES .....</b>	<b>.....</b>
<b>POST-CIRCUIT CHANGE.....</b>	<b>.....</b>
<b>AFTER ENTER BUTTON IS PRESSED: .....</b>	<b>.....</b>
<b>IMPORTANT.....</b>	<b>.....</b>
<b>TO COMPLETE A CIRCUIT CHANGE: .....</b>	<b>.....</b>
<b>IDENTIFYING PROPER HUMIDIFICATION .....</b>	<b>25</b>
<b>CHAPTER 6: START UP .....</b>	<b>.....</b>
<b>MEASURING &amp; DISPLAYING PRESSURES .....</b>	<b>27</b>
<b>CHOOSING STARTING VALUES .....</b>	<b>28</b>
<b>6 STEPS TO START HFV .....</b>	<b>29</b>
<b>CHAPTER 7: PATIENT MANAGEMENT .....</b>	<b>.....</b>
<b>CLINICAL OBJECTIVES .....</b>	<b>32</b>
<b>OXYGENATION .....</b>	<b>33</b>
<b>OXYGENATION OVEREXPANDED LUNGS .....</b>	<b>35</b>
<b>FINDING OPTIMAL PEEP .....</b>	<b>36</b>
<b>VENTILATION .....</b>	<b>37</b>
<b>UNDERSTANDING SERVO PRESSURE .....</b>	<b>39</b>
<b>CHAPTER 8: SUCTIONING THE PATIENT .....</b>	<b>.....</b>
<b>SUCTION PROCEDURE #1 .....</b>	<b>41</b>

# In-service Manual

## TABLE OF CONTENTS

SUCTION PROCEDURE #2 .....	42
• READY LIGHT MUST BE ON!.....	
• INSTILL INTO JET PORT THEN RECONNECT LIFE PULSE CIRCUIT.....	
• ONE PERSON DISCONNECT CV CIRCUIT FROM LIFEPORT.....	
• SECOND PERSON APPLIES SUCTION GOING INTO AND OUT OF THE ET TUBE.....	
SUCTION PROCEDURE #3 .....	44
• SELECT AN IN-LINE SUCTION SYSTEM COMPATIBLE WITH THE LIFEPORT ADAPTER.....	
• SELECT AN IN-LINE SUCTION SYSTEM WITH A CATHETER THAT IS STRAIGHT FOR THE FIRST FEW INCHES.....	
• SUCTION ACCORDING TO PROCEDURE 1 OR 2 DESCRIBED EARLIER IN THIS SECTION.....	
<b>CHAPTER 9: WEANING .....</b>	
GENERAL GUIDELINES FOR WEANING.....	45
<i>GENERAL GUIDELINES FOR WEANING</i> .....	
<b>CHAPTER 10: VENTILATOR ALARMS.....</b>	
READY LIGHT ON.....	48
ALARM LIMITS .....	49
<b>JET VALVE FAULT</b> .....	50
VENTILATOR FAULT: HFV CONTINUES RUNNING .....	51
VENTILATOR FAULT:HFV STOPS RUNNING.....	52
VENTILATOR FAULT: CODE 10.....	53
<b>LOW GAS PRESSURE</b> .....	54
CANNOT MEET PIP.....	55
LOSS OF PIP .....	56
HIGH PIP.....	57
<b>CHAPTER 11: INTERPRETING VENTILATOR ALARMS.....</b>	
<b>ALARM DISPLAY</b> .....	58
LOOK AT THE PATIENT .....	59
USE COMMON SENSE.....	60
KNOW THE LIFE PULSE.....	61
COMMON THINGS HAPPEN COMMONLY .....	62
USE AVAILABLE RESOURCES.....	63
<b>CHAPTER 12: HUMIDIFIER ALARMS.....</b>	
HUMIDIFIER OPERATION .....	65
CIRCUIT FAULT: LEVEL ALARM.....	66
WATER LEVEL SENSING .....	67
CIRCUIT TEMPERATURE.....	68
TEMPERATURE CONTROLS.....	69
SETTING CARTRIDGE TEMPERATURE .....	70
CONDENSATION PROBLEMS.....	71
MANUALLY PURGING.....	72
HIGH / LOW WATER LEVEL.....	73
HIGH / LOW TEMPERATURE.....	74
<b>APPENDIX A: POST-TEST QUESTIONS.....</b>	
<b>APPENDIX B: POST-TEST ANSWERS.....</b>	

Each chapter begins with a chapter designation



Each page will list its content: large, bold, capital letters



# HOW TO USE THIS MANUAL

## Objectives

1. Understand how to use this manual.
2. Know how to navigate to the information you need.



*Each chapter includes objectives for the reader*

Text that lists sequential procedures:

1. Is numbered
2. Like this

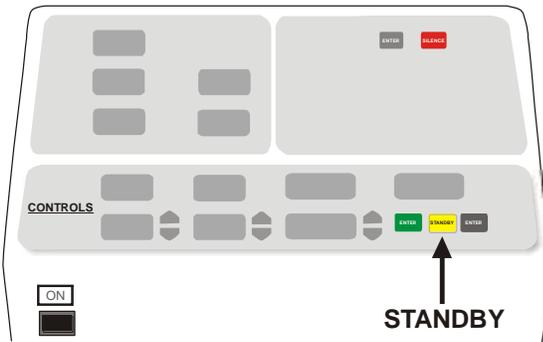
Otherwise, lists will be:

- Bulleted
- Like this

Text that instructs you to press a button will highlight the button's font like this: press **MENU**



*Text will appear in the right column*



*Graphics and instruction boxes will appear in the*



## INSTRUCTION BOXES

Boxes containing instructions and summaries of procedures will appear in lightly shaded boxes and will look like this.

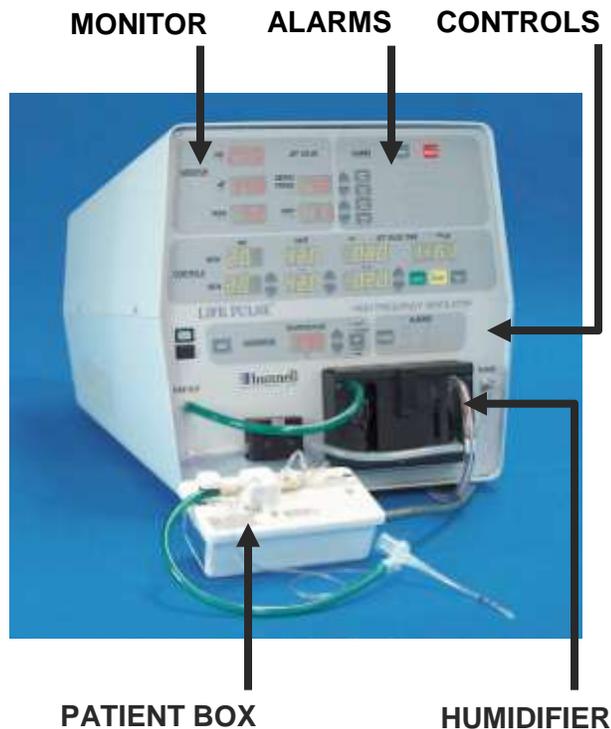
**WARNING:** Warnings will also appear in lightly shaded boxes and will look like this.

## Objectives

1. Know the 5 subsystems of the Life Pulse and their purposes.
2. Understand the relationship between the Life Pulse and the conventional ventilator.
3. Know the structure and function of the LifePort adapter.

The Life Pulse High-Frequency Ventilator is a microprocessor-controlled infant ventilator capable of delivering and monitoring between 240 and 660 heated, humidified breaths per minute.

The Life Pulse is composed of 5 subsystems:



**MONITOR:** Displays patient and machine pressures.

**ALARMS:** Indicates various conditions that may require attention.

**CONTROLS:** Regulates the On-Time, Peak Inspiratory Pressure, and Rate of the HFV breaths.

**HUMIDIFIER:** Monitors and controls the temperature and humidification of gas flowing through the disposable humidifier circuit to the patient.

**PATIENT BOX:** Contains the pinch valve that breaks the flow of pressurized gas into tiny jet pulses and sends pressure information back to the ventilator's microprocessor.

Together, these elements form a system that offers a variety of options for managing patients and the potential for improving blood gases using less pressure.

INDICATOR LED	MODEL 203	MODEL 203A
STANDBY	Red	Yellow
TEST	Red	Yellow
JET VALVE OFF	Red	Yellow
READY	Red	Green
WAIT	Red	Yellow
CIRCUIT	Red	Yellow
CARTRIDGE	Red	Yellow

**NOTE:** Graphics that display illuminated indicator lamps (LEDs) in this manual reflect Life Pulse model 203. For model 203A, please refer to the table at right:

# HFV with CV

## VENTILATOR FUNCTIONS

### LIFE PULSE

- High-frequency breaths
- Airway pressure monitoring
- Humidification
- Alarms

### CONVENTIONAL VENTILATOR

- Regulate PEEP
- Fresh gas for spontaneous breathing
- Supplementary IMV
- Airway dilation

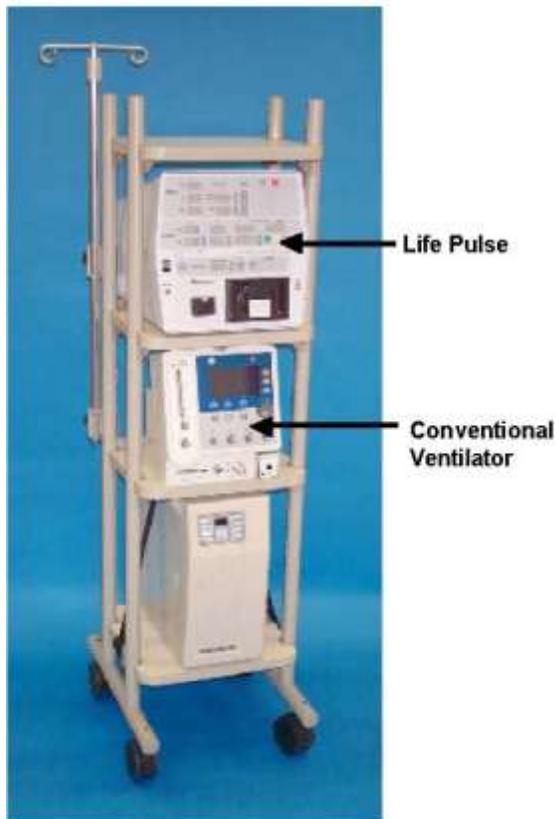
The Life Pulse is used in conjunction with a conventional infant ventilator. The conventional ventilator has 4 functions:

- provides fresh gas for the patient's spontaneous breathing,
- regulates PEEP,
- provides supplementary IMV when needed, and
- provides periodic dilation of airways when needed.

The purpose of the supplementary IMV is to provide background breaths sufficient to recruit atelectatic alveoli.

The purpose of the PEEP provided by the conventional ventilator is to maintain the inflation of alveoli with adequate FRC.

Using IMV periodically to dilate airways without interrupting the Life Pulse affords opportunities to ventilate areas downstream from airway restrictions.



# LifePort Adapter

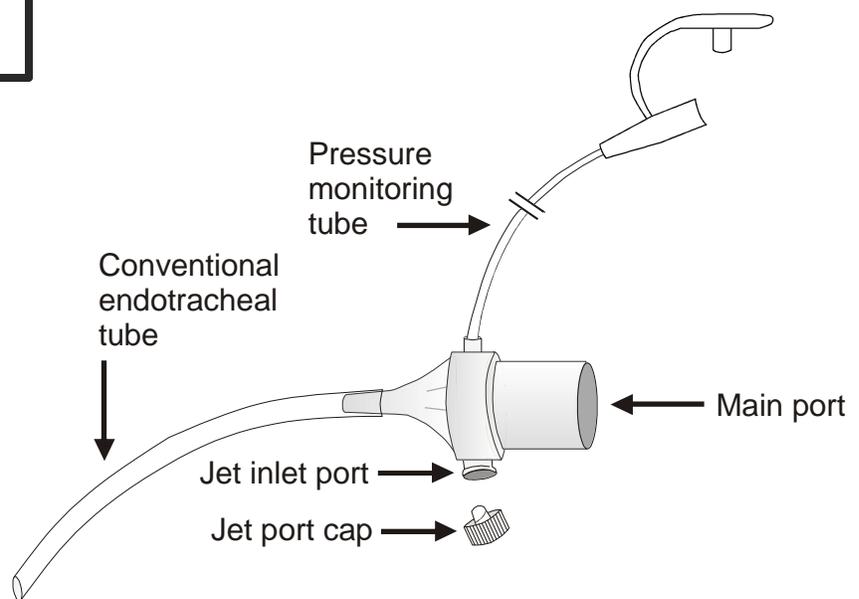
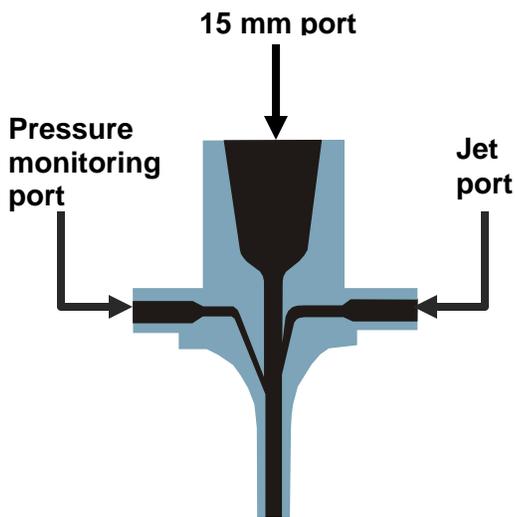


The LifePort adapter allows both the conventional ventilator and the Life Pulse to be connected to a patient. The LifePort has three main features:

- **15 mm Port:** provides the standard connection to the conventional ventilator.
- **Jet Port:** the entrance for the high-frequency pulses provided by the Life Pulse.
- **Pressure Monitoring Tube:** allows the Life Pulse to display approximations of distal tip airway pressures.

Accurate pressure measurements through the LifePort are fed back to the ventilator and provide the Life Pulse with information necessary to control peak inspiratory pressure (PIP) .

For example, if the measured PIP is higher than the set PIP, the Life Pulse stops pulsing. If the PIP suddenly reaches automatically set criteria, the Life Pulse dumps the stored Servo Pressure to insure that the Life Pulse will not deliver excess gas to the patient.



### Objectives

1. Understand the connections to the electrical power, air, oxygen, and water necessary for the Life Pulse to function.
2. Know how to install the humidifier cartridge and circuit.



The Life Pulse should be positioned so that the displays are easy to read and its controls and the conventional ventilator controls are within easy reach. The cart is on 5 inch, lockable casters for easy portability and stability.

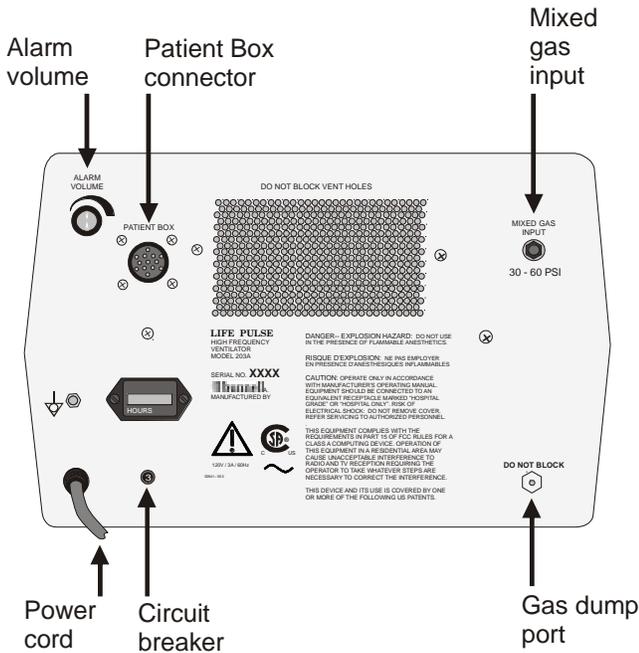
The Bunnell ventilator cart is designed to carry most of the patient's cardiopulmonary equipment. For example, oxygen analyzers and other monitors can be placed on the top shelf.

The Life Pulse is typically placed on the second shelf, the conventional ventilator on the third, and an uninterruptible power supply on the bottom.

Setup procedures for the Life Pulse include making connections in three places:

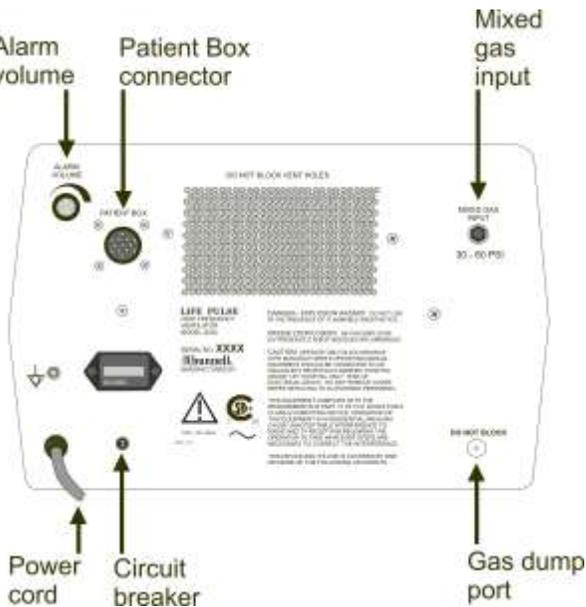
- the Rear Panel,
- the Front Panel, and
- the Patient Box.

# REAR PANEL CONNECTIONS



**Life Pulse Model 203**

1. Plug in the power cord to a standard 110 volt outlet or, preferably, an uninterruptible power supply.
2. Connect a high-pressure oxygen hose from a low flow air/oxygen blender (0-30 L/min) or the output from the low flow port (2-100 L/min) of a standard blender to the Mixed Gas Input fitting. A minimum pressure of 30 psi is required to operate the Life Pulse.
3. Attach an oxygen analyzer to the Oxygen Sensor in order to monitor  $FiO_2$  (*not applicable to serial number 2414 or higher*), or monitor  $FiO_2$  from the air/oxygen blender output.
4. With Model 203, plug in one of a variety of recording devices to the Analog Output to monitor airway pressure graphically (*Optional*).
5. Connect the Patient Box to the ventilator by its electrical cable attached to the multi-pinned connector.
6. Adjust the volume of the audible alarms using the Alarm Volume dial.

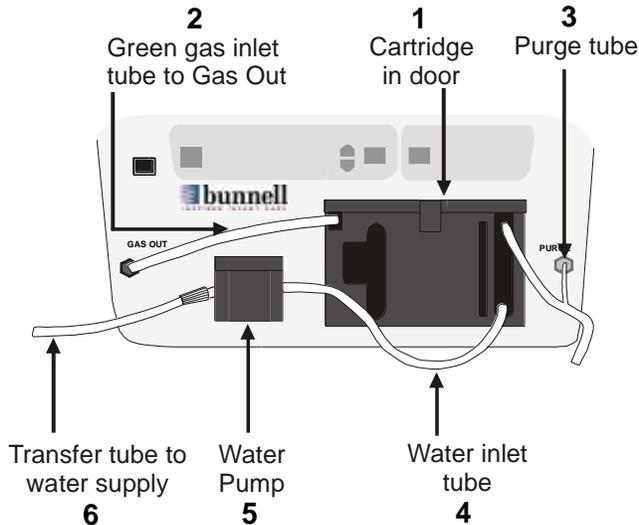


**Life Pulse Model 203 A**

## CHECKLIST Rear Panel Connections

- Power cord
- Gas in from blender
- O<sub>2</sub> Sensor (Only SN's 2413 and lower)
- Patient Box
- Alarm volume

# FRONT PANEL CONNECTIONS



CHECKLIST	
Front Panel Connections	
1	Cartridge in and door latched
2	Green gas inlet tube
3	Purge tube
4	Water inlet tube
5	Water pump
6	Water supply bag

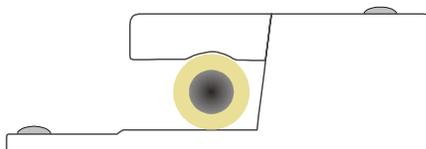
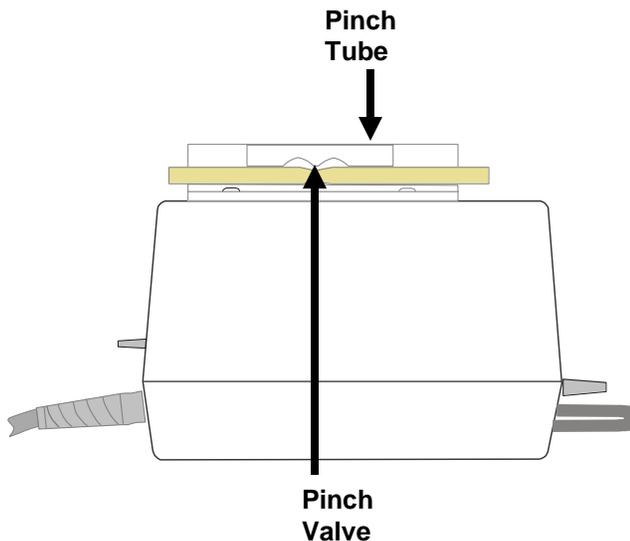
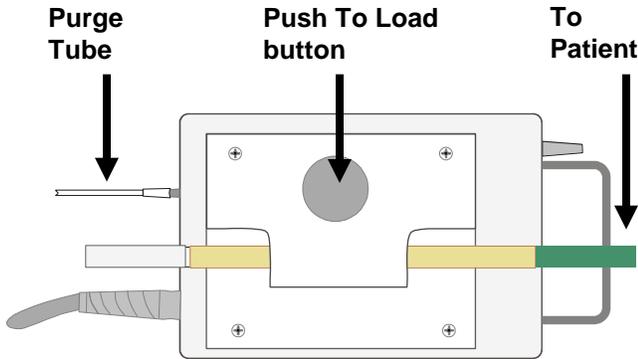
1. Insert the Humidifier Cartridge into the cartridge door. Latch the door shut to make all electrical connections between the cartridge and the Life Pulse.
2. Connect the green gas inlet tube to the large barbed connector labeled GAS OUT.
3. Connect the small diameter purge tube to the barbed connector labeled PURGE.
4. Locate the water inlet tube, a clear tube running from the lower right corner of the cartridge with a check valve and a Luer fitting on the end.
5. Install the water inlet tube by placing the clear tube into the pump housing, closing the pump door securely to pinch the water inlet tube inside, and connect the water transfer tube to the Luer connector on the end of the water inlet tube.
6. Tap the sterile water bag with the other end of the water transfer tube and open the tubing clamp.

**Use only sterile water** for the cartridge water supply.

**WARNING:** The water supply should be positioned at or below the level of the humidifier cartridge to decrease the potential of overfilling the cartridge by gravity feed.

**WARNING:** The water inlet tube of the humidifier cartridge/circuit must be latched into the pump housing to prevent cartridge overflow and delivery of water to the patient by gravity feed.

# PATIENT BOX CONNECTIONS



End view

1. Locate the soft pinch tubing portion of the circuit just beyond where the red and white wires inside the circuit terminate.
2. Place the pinch tubing in line with the pinch valve assembly.
3. Hold the pinch tubing on each side of the pinch valve assembly.
4. Press the PUSH TO LOAD button with one finger.
5. Slide the pinch tubing into the pinch valve assembly until you feel it snap into place.

The illustrations on the left show a proper pinch tubing placement. The entire width of the pinch tube should be within the pinch valve jaws.

6. Connect the small purge tube to the barbed connector labeled FROM PURGE.

The disposable humidifier cartridge and circuit are now ready for operation, and the Life Pulse is ready to be turned on.

## CHECKLIST Patient Box Connections

- Pinch tubing in pinch valve
- Purge tube connect

## SETUP CAUTIONS

Two cautions should be noted about the Set Up procedure:

*First*, patients are often placed on the Life Pulse on an emergency basis. You can save time if the ventilator is stored clean and partially set up, ready for use.

**Do NOT install the pinch tube in the pinch valve prior to actual patient set-up.**

The disposable cartridge/circuit, water transfer tube, and a test lung can be placed with the Life Pulse. If using the Bunnell Cart, everything necessary to begin high-frequency jet ventilation can be wheeled to the patient's bedside.

*Second*, notice that the installation description includes only cartridge/circuit tubing supplied by Bunnell Incorporated.

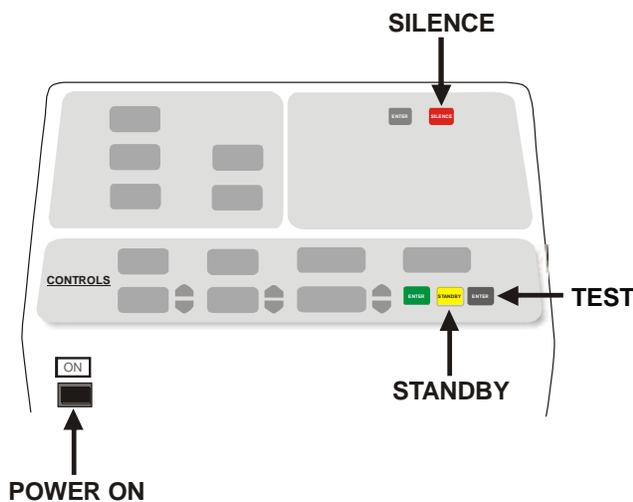
**Do NOT make modifications to the supplies or the set up procedure!**

Pressures cannot be monitored accurately and the Life Pulse will not work properly if other equipment is teed into the pressure monitoring tube or if leaks are present in the circuit.

# VENTILATOR CONTROLS & TEST PROCEDURE

### Objectives

1. Be able to attach the Life Pulse circuit to the LifePort adapter.
2. Understand the ON, STANDBY, ALARM SILENCE, TEST, and ENTER buttons.
3. Know how to perform a Life Pulse systems test and know the meaning of VENTILATOR FAULT alarms 02, 03, and 04.
4. Be able to enter NEW settings and convert them to NOW settings.



This section discusses how to manipulate the **CONTROLS** and perform a systems test.

When the ON button is pressed, the Life Pulse activates into the Standby mode with an audible alarm sounding.

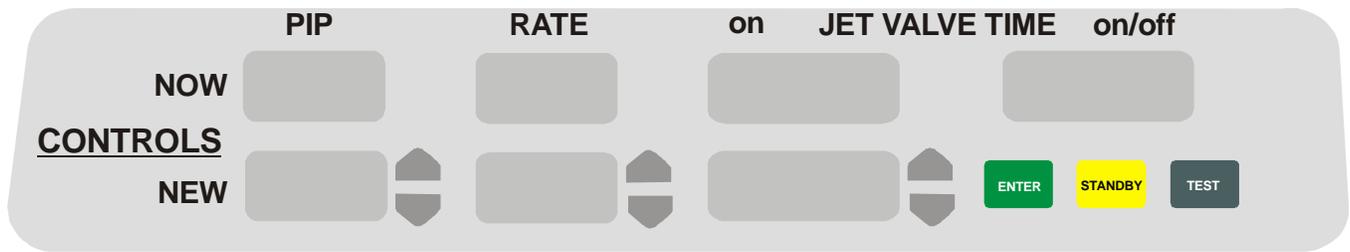
The Standby mode is indicated by a small light in the corner of the **STANDBY** button and an audible alarm every 30 seconds. The alarm may be silenced by pushing the **SILENCE** button.

Once the 60-second alarm silence time has expired, the audible alarm will sound 6 beeps every 30 seconds to remind you that the Life Pulse is in the Standby mode and not operating.

The Life Pulse can monitor conventional ventilator and other high-frequency ventilator pressures in the Standby mode.

This information will be displayed in the **MONITOR** section.

# THE CONTROLS SECTION



There are only three setting parameters in the **CONTROLS** section: PIP (Peak Inspiratory Pressure), RATE, and JET VALVE ON Time, which is nearly synonymous with Inspiratory Time.

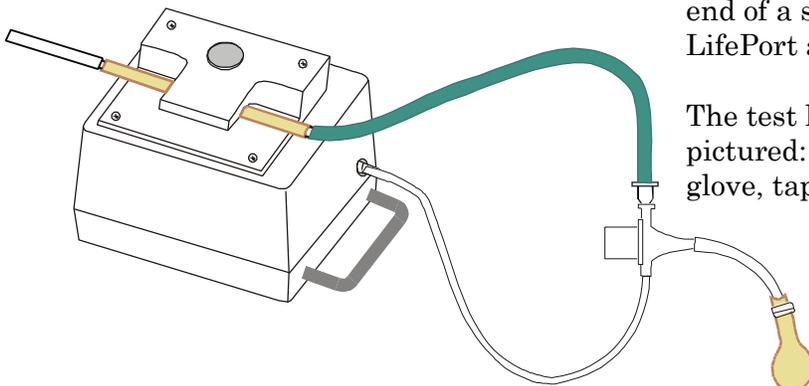
These settings may be changed by pressing the up and down arrow buttons next to their respective displays.

1. Press the **ENTER** button to transfer the **NEW** settings into the **NOW** settings (the settings the patient will receive).
2. Press the **STANDBY** button to place the Life Pulse into the Standby mode. The Life Pulse stops producing high-frequency jet ventilation and only the **NEW** settings are displayed.

A systems test should be performed to insure that the Life Pulse is in good operating condition before connecting the system to a patient.

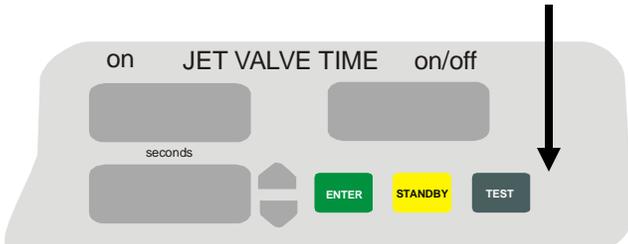
A test lung must be attached to the patient end of a standard endotracheal tube and LifePort adapter prior to performing the Test.

The test lung can be as simple as the one pictured: a finger cot, or the finger of a rubber glove, taped lightly to the tip of the ET tube.

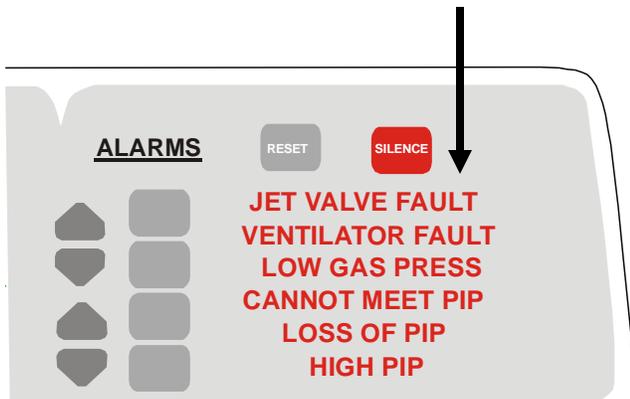


# PERFORMING A TEST

Press **TEST** button to begin systems test.



All possible alarms will be illuminated briefly during the systems test.



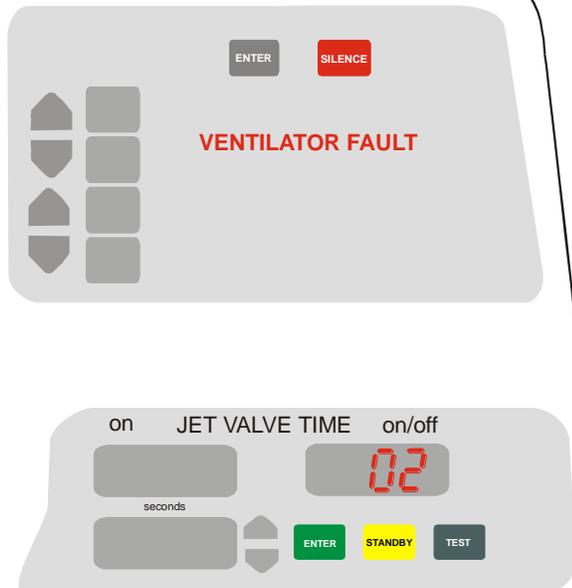
The Life Pulse's systems test will ensure that the ventilator is operating according to specifications. To perform the test, follow these steps:

1. Attach a LifePort adapter to an ET tube and test lung.
2. In the Standby mode, connect the patient end of the Life Pulse circuit, coming from the pinch valve, to the Jet port on the side of the LifePort adapter.
3. Connect the clear pressure monitoring tube of the LifePort adapter to the Patient Box barbed connector labeled MONITORING LUMEN.
4. Press the TEST button. An automatic test begins which determines the integrity of all the ventilator's electronics and valves.
5. Observe the front panel to assure all LEDs and displays are functional, and listen to make sure the audible alarm is functioning properly. If no problems are detected, all the ventilator displays will illuminate 1 through 9 in sequence and all the alarm messages will be displayed.

The Test procedure will end with the Life Pulse in the Standby mode and an audible alarm sounding.

6. Silence the audible alarm by pressing the SILENCE button. The audible alarm stops for 60 seconds.
7. Once the internal Test passes, perform an operational test using the test lung. A conventional ventilator is not needed and the LifePort adapter 15mm connector is left open to the room.
8. Press the ENTER button to activate the default control settings (20, 420, 0.02).
9. Once the PIP is stable, the Ready light will activate. Make sure the pressures are stable and the PEEP is reading  $0.0 \pm 1$  cm H<sub>2</sub>O.
10. If the PEEP is  $> \pm 1$  cm H<sub>2</sub>O, switch out the Patient Box and repeat the operational test.

# A FAILED TEST



If an internal fault is detected, the test sequence will stop, **VENTILATOR FAULT** will be displayed in the ALARMS area, and a code number **02**, **03**, or **04** will appear in the ON/OFF window of the CONTROLS section.

A VENTILATOR FAULT code may or may not mean the Life Pulse has a serious problem.

For example, if the purge tube is disconnected during the Test, either at the Patient Box or the front panel, a VENTILATOR FAULT 02 will be displayed.

- VENTILATOR FAULT 02 - check the purge tube for a disconnect at the front panel or the Patient Box. This fault will also occur if the pressure transducer in the Patient Box has failed.
- VENTILATOR FAULT 03 - check the green gas inlet tube for a disconnect at the GAS OUT connector. This fault may also occur if one of the Servo Pressure control valves is not working properly.
- VENTILATOR FAULT 04 - You may observe the Life Pulse performing this check by watching the code display area closely. As the test is performed, the display momentarily flashes 04. If the test is passed, the 04 disappears. If it fails, the 04 stays lit, a VENTILATOR FAULT code appears, and an audible alarm sounds.

## CHECKLIST Fault Code Numbers

- 02** Purge tube disconnect or pressure transducer failure
- 03** Green gas inlet tube disconnect, pinch tube incorrectly installed, or stuck Servo Pressure control valve
- 04** Electrical component failure

**WARNING:** All patient connections to the Life Pulse circuit must only be made while the Life Pulse is in the **STANDBY** mode. Failure to comply may result in a high volume of gas being delivered to the patient.

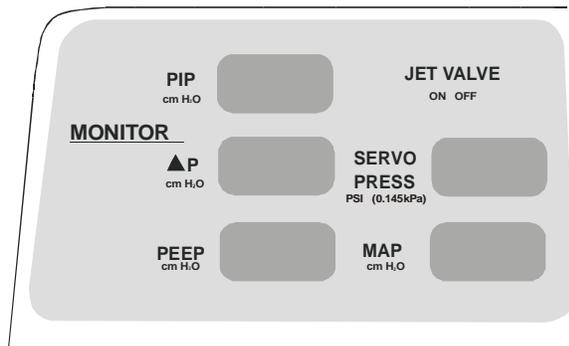
Once it has successfully passed the test, and after operating properly on a test lung, the Life Pulse is ready for clinical use.

If the Life Pulse is unable to achieve the desired settings on a test lung, or the cause of a VENTILATOR FAULT cannot be determined, or an 04 stays displayed at the end of the test, **call the Bunnell Hotline (1-800-800-4358).**

# PRESSURE MONITORING

## Objectives

1. Appreciate the advantages of the LifePort Adapter and the purpose of each of its 3 ports.
2. Understand the parameters displayed in the MONITOR section and where they are measured.
3. Understand Servo Pressure and its clinical relevance.
4. Understand the function of the PURGE.



The **MONITOR** displays reflect the pressures at the tip of the endotracheal tube and the internal Servo or drive pressure of the Life Pulse. If the Life Pulse is in Standby, and there is no patient connected to the Patient Box, the displays will all read zero.

Once the pressure monitoring tube of the LifePort adapter has been connected to the Patient Box, the Life Pulse, even in its Standby mode, will begin to monitor the pressures being delivered by the conventional ventilator. These pressures are updated in the MONITOR displays every 10 seconds.

The Life Pulse monitors:

- **PIP:** Peak Inspiratory Pressure,
- **PEEP:** Positive End-Expiratory Pressure,
- **MAP:** Mean Airway Pressure,
- **ΔP:** PIP minus PEEP, roughly equivalent to tidal volume, and
- **SERVO PRESSURE:** internal driving pressure; always 0.0 in Standby mode.

## MONITOR DISPLAYS

**PIP**

**PEEP**

**MAP**

$\Delta P$  (i.e.,  $V_T$ )

**SERVO PRESSURE**

- **PIP:** the average of maximum airway pressures measured during a set time period
- **PEEP:** the average minimum airway pressure
- **MAP:** is an average of pressures measured from the total pressure waveform. It includes pressures produced by high-frequency ventilation, conventional ventilation, or spontaneous breathing.
- **$\Delta P$ :** (Delta P) simply the arithmetic difference between PIP and PEEP.  $\Delta P$  is roughly proportional to Tidal Volume and its importance in clinical decision making will become more apparent in the discussion of patient management.
- **SERVO PRESSURE:** the internal drive pressure of the Life Pulse; indicates how much gas flow must be produced to meet the NOW PIP, Rate, and On-Time requested by the operator.

Servo Pressure is regulated by the ventilator's microprocessor and is outside the control of the operator. Bigger patients, or those with more compliant lungs, will require higher Servo Pressures whereas those infants with smaller and/or less compliant lungs will require lower Servo Pressures.

Servo Pressure is an indication of how much gas flow the Life Pulse must generate to meet the settings requested. Servo Pressure changes above or below the established operating level for a particular patient may be a result of changes in lung compliance, airway resistance, or lung volume.

Servo Pressure changes give an early indication that the patient's condition may be improving or worsening.

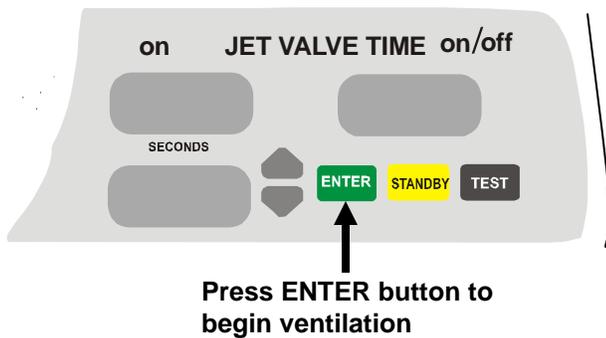
### **SERVO PRESSURE ↑**

- Improved compliance and/or resistance
- Air leak
- Disconnected tube

### **SERVO PRESSURE ↓**

- Worsening compliance and/or resistance
- ET tube obstruction
- Tension pneumothorax
- Patient needs suctioning
- Right mainstem intubation

# PRESSING ENTER BUTTON



When the **ENTER** button is pressed, the microprocessor will begin increasing the Servo Pressure from zero to whatever value will produce the NOW PIP at the end of the NOW ON-TIME at the NOW RATE.

Although it will typically take a short time for the actual PIP to reach the NOW PIP, the displayed PIP will equilibrate slower because of the averaging characteristics of the display. Thus, it may take longer (typically within a minute) for the monitored PIP to reach the NOW PIP.

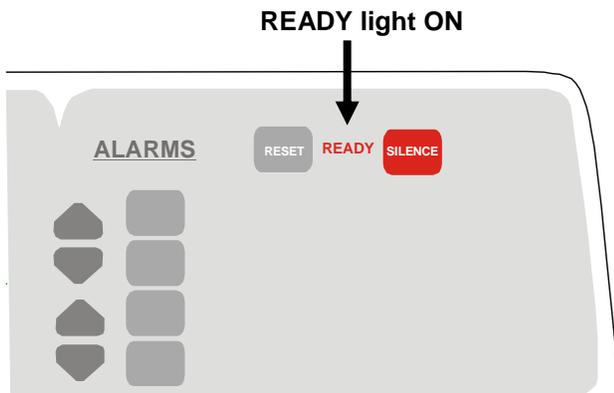
When the monitored NOW PIP is stable for 20 seconds, the **READY** light will illuminate. The **READY** light indicates the Life Pulse is providing ventilation at the settings you have requested, and alarm conditions that are set automatically have been established.

(The specific criteria which produce the **READY** condition are discussed in the **ALARMS** section, but the **READY** condition is mentioned here because the monitoring specifications change after the **READY** light is on: the display is updated every 2 seconds.)

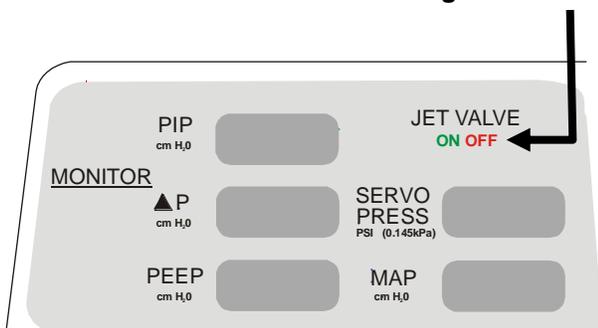
The **JET VALVE ON/OFF** lights turn on and off in conjunction with the pinch valve that is located in the Patient Box. **ON** means the valve is open. **OFF** means the valve is closed.

These lights serve as a visual check on the status of high-frequency ventilation in general and on the extent to which the patient or the conventional ventilator may be causing interruptions of the Jet pulses.

The Life Pulse will sense a high pressure and will pause whenever the monitored PIP exceeds the NOW PIP. Ventilation resumes when the PIP drops below the set level. Monitor such interruptions visually by watching the **ON/OFF** lights.



Jet Valve ON/OFF lights flash



# PURGE PAUSES

The Life Pulse may pause periodically and briefly during operation for no apparent reason. Such pauses can occur during clinical use or when you are operating on a test lung.

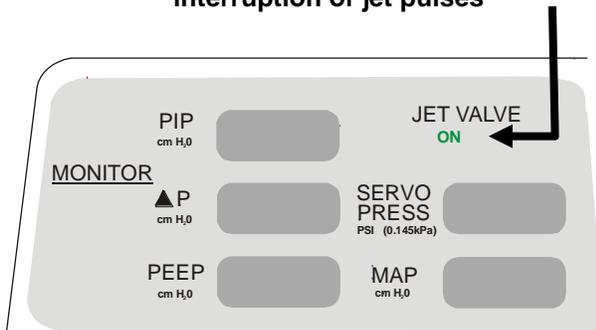
These brief pauses are usually a result of the purge of the pressure monitoring tube that takes place once every 15 seconds.

The Purge valve is located next to the pressure transducer inside the Patient Box. When the valve opens it allows a pulse of dry air to flush the pressure monitoring tube.

On rare occasions, the purge may cause high pressure to be measured by the transducer that, in turn, makes the Life Pulse skip a beat in conjunction with its built-in response to high pressures.

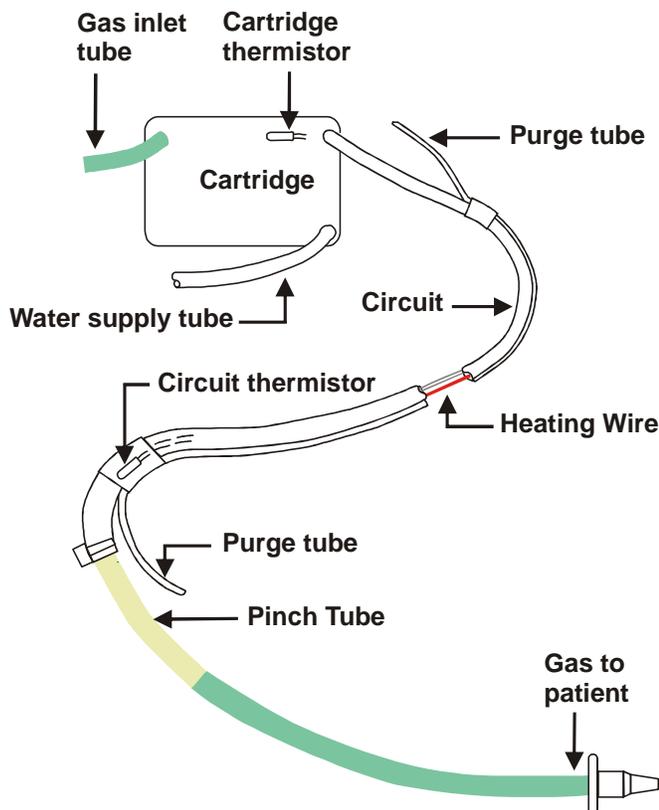
Do not be concerned if the Life Pulse appears to hiccup every once in a while. If you time the pauses, you will find that they occur at some multiple of 15 seconds. (This pause usually will only occur on rates of 550 bpm or greater.)

**Extended pauses of the Green Jet Valve ON light indicate an interruption of jet pulses**



**Objectives**

1. Describe the flow of gas from the ventilator through the entire length of the Humidifier Cartridge/Circuit.
2. Understand the purpose of humidification and how it is produced and regulated.
3. Learn to adjust the temperature manually in the cartridge and the circuit.
4. Understand the function of the pinch tube portion of the circuit.



The Life Pulse humidifier uses a one-piece disposable cartridge and tubing set called the humidifier cartridge/circuit. This item is often referred to as “the cartridge”, “the circuit”, or “the patient breathing circuit”.

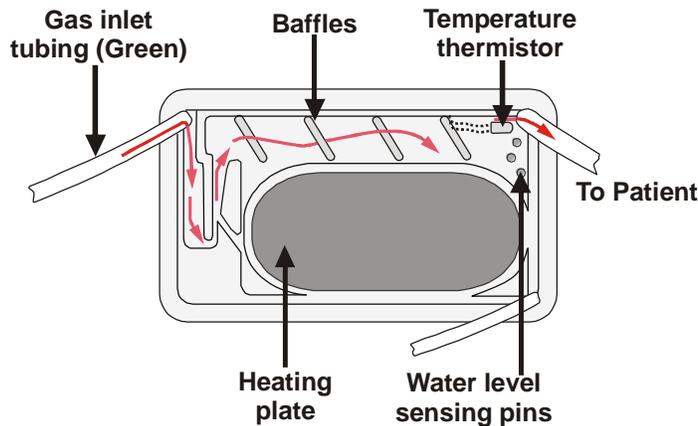
All are terms that refer to all or part of the humidifier cartridge/circuit. It is pre-assembled and contains the heating wire, thermistors, and all connections needed for operation.

Gas from the GAS OUT connector on the front panel of the ventilator flows into the humidifier cartridge via the green gas inlet tube.

The shorter clear tube is the water inlet tube and contains a check valve that prevents gas from leaking out when the water supply bag is disconnected.

Water is pumped into the cartridge against the cartridge pressure. Once the water inlet tubing is securely closed in the pump housing, water and air cannot be forced back into the water supply bag.

# GAS FLOW THROUGH HUMIDIFIER



The gas flows from the Life Pulse to the patient as follows:

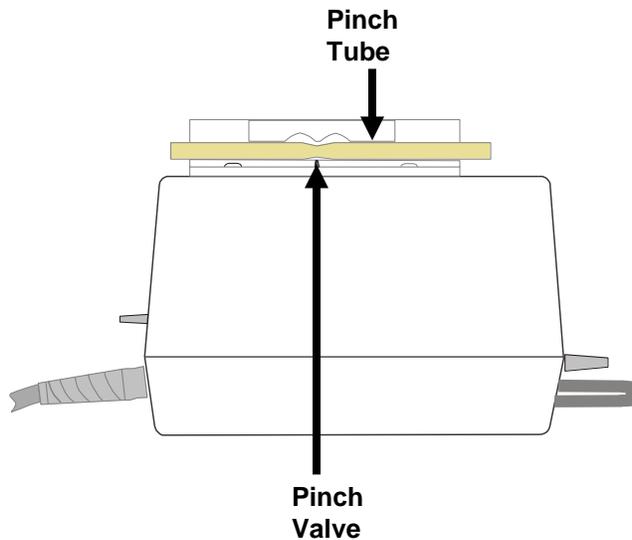
- The gas enters the cartridge through the green gas inlet tube.
- The gas flows down below the water level then back up through a venturi mechanism, which atomizes some of the heated water.
- The gas then flows over the heated reservoir of water and past a series of baffles which knock out water droplets.
- The humidified gas passes over the cartridge thermistor which measures the temperature.
- The microprocessor uses this temperature to regulate the amount of heat delivered to the cartridge through the metal heating plate.
- This feedback control system uses the **CARTRIDGE** temperature setting on the humidifier front panel as its set point and **controls the humidification of gas being delivered to the patient**, not the temperature.
- Heated and humidified gas leaves the cartridge and enters the circuit tubing with the red and white wires inside.

The temperature thermistor at the tip of the white circuit wire measures the actual temperature of the humidified gas in the circuit just before the Patient Box. The value is displayed as **CIRCUIT TEMP** in the humidifier display section.

The red wire is a heating element that is turned on and off according to feedback from the circuit temperature.

# GAS FLOW THROUGH HUMIDIFIER (cont.)

- Using the **CIRCUIT temperature** setting on the humidifier front panel as its set point, the microprocessor **controls the temperature of the gas being delivered to the patient.**



The heating wire also minimizes the amount of condensation in the tubing to control “rainout.”

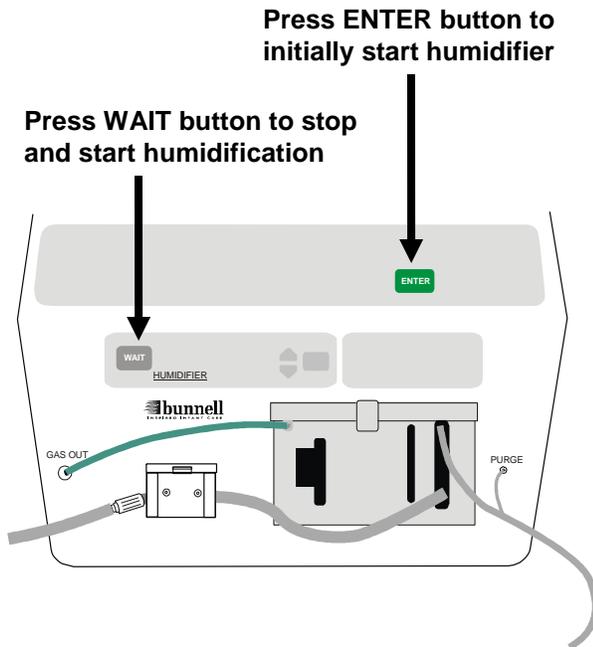
- The heated and humidified gas flows into the pinch tube section of the circuit where the pinch valve breaks the flow into breaths.
- The gas begins to cool as it leaves the pinch valve and condensation occurs as a result of the cooling.

The temperature of the gas that enters the LifePort adapter will be approximately 3° C less than when it was last measured by the circuit thermistor.

Therefore, the **CIRCUIT** temperature is automatically set at 40° C on the front panel by the microprocessor.

The intention is to deliver the gas to the patient at close to 37° C, normal body temperature.

# STARTING THE HUMIDIFIER



The Life Pulse Humidifier requires little operator intervention. The temperature of the gas is regulated by feedback control from the point where it enters the cartridge to the point where it enters the Patient Box.

When the Life Pulse is first turned on, the ventilator comes up in its Standby mode and the humidifier is in its WAIT mode. The two modes are equivalent; there is no ventilation and no humidification or heating being done in these modes.

When the ENTER button is pressed, the light in the corner of the WAIT button goes off and the humidifier automatically begins functioning. The pump has 86 seconds to fill the cartridge to the proper level.

When the STANDBY button is pressed, the light in the corner of the WAIT button is lit and the humidifier assumes its WAIT mode.

The humidifier WAIT mode may also be entered independently by pressing the WAIT button. In this case, the light in the corner of the WAIT button begins blinking on and off.

Press the WAIT button again to bring the humidifier back into operation and reset the 86-second timer for the water pump,

# CHANGING THE CIRCUIT

When replacing the circuit, place the humidifier in its WAIT mode to turn off the circuit and cartridge heaters until the replacement circuit is installed. This procedure is best performed with 2 people. Both people should perform their tasks simultaneously.

The actual changing of the circuit should be performed with the Life Pulse in the Standby mode, but many steps can be taken to prepare for the actual circuit change **as long as the Life Pulse is in the READY condition.**

These steps are as follows:

1. Lay the new circuit next to the circuit in use.
2. With the ventilator still running, press the humidifier WAIT button.
3. Clamp off the water transfer tube connecting the water supply with the water inlet tube.
4. Disconnect the water transfer tube from the old cartridge and attach it to the water inlet tube of the new cartridge.
5. Disconnect the Purge tube.
6. Open the cartridge door.

The Life Pulse continues to ventilate even with the cartridge door open, because pressure remains in the cartridge and circuit, and the actual pulsing is done in the Patient Box, which is still connected. Alarms can be silenced as necessary.

## FRONT PANEL DUTIES

1. The person attending the Patient Box can disconnect the purge tube from the Purge barbed connector and attach the purge tube from the new circuit.
2. When both operators are ready, press the **STANDBY** button to stop the Life Pulse.

## CIRCUIT CHANGE PREPARATIONS

### Checklist

With Life Pulse Operating:

- Position new circuit,
- Press WAIT button,
- Clamp H<sub>2</sub>O transfer tube,
- Disconnect H<sub>2</sub>O transfer tube from old circuit,
- Reconnect H<sub>2</sub>O transfer tube to new circuit,
- Disconnect Purge tube from the front of the Life Pulse,
- Unlatch and open cartridge door, and
- Disconnect purge tube from Patient Box.

## FRONT PANEL DUTIES

- Press STANDBY button,
- Disconnect green gas inlet tube,
- Open pump door,
- Remove used cartridge,
- Insert new cartridge,
- Connect green gas inlet tube,
- Install new water inlet tube into pump housing,
- Open clamp on H<sub>2</sub>O transfer tube
- Press ENTER button.

# CHANGING THE CIRCUIT

## (cont.)

Once the Life Pulse has been placed in the Standby mode, manually ventilate the patient or adjust the conventional ventilator settings to provide the patient with adequate ventilatory support while the Life Pulse is not running. With two people, one at the ventilator and one at the Patient Box, the circuit change can be performed more quickly.

### PATIENT BOX DUTIES

- Disconnect Life Pulse circuit at ET tube connections,
- Remove pinch tube from pinch valve,
- Insert new pinch tube into pinch valve,
- Connect new Life Pulse circuit at ET tube connections, and
- Press ENTER button to resume ventilation.

### PATIENT BOX DUTIES

1. The person at the Patient Box disconnects the Jet port of the old Life Pulse circuit from the side of the LifePort adapter.
2. Remove the old pinch tube from the jaws of the pinch valve in the Patient Box and install the pinch tube of the new circuit.
3. Attach the new circuit to the Jet port of the LifePort adapter.

### FRONT PANEL DUTIES

1. The person at the ventilator can disconnect the gas inlet tube and remove the cartridge from its holder,
2. Place the new cartridge into the cartridge door and latch it,
3. Connect the green GAS OUT tube and purge tube to their ports,
4. Install the water inlet tube into the pump housing and latch the door securely; with the pump door latched open the clamp on the water transfer tube.
5. Press the ENTER button to reestablish high-frequency ventilation and clear a LOSS OF PIP alarm that may result from tubing disconnections.

### POST-CIRCUIT CHANGE

#### *After ENTER button is pressed:*

- Close and latch cartridge door,
- Reconnect purge tube at Life Pulse front panel,
- Reconnect purge tube at Patient Box,
- Make sure Humidifier is **not** in WAIT mode,
- Recheck all connections, and
- Press ENTER button again if necessary.

# CHANGING THE CIRCUIT

(cont.)

## IMPORTANT

### *To complete a circuit change:*

- Observe water filling cartridge,
- Observe water pump stopping when cartridge fills to proper level, and
- Observe humidity appearing in the green portion of the circuit.

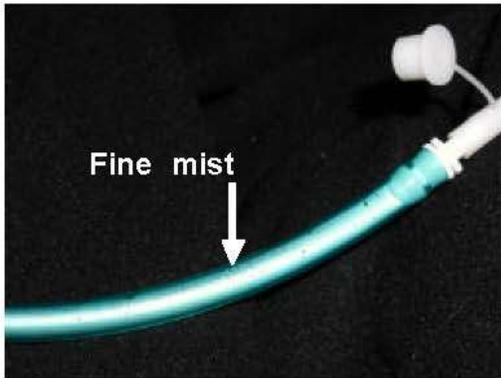
6. After the ventilator is running, make sure the purge tube is attached at both the ventilator and Patient Box barbed connectors.
7. If necessary, adjust the conventional ventilator settings back to their previous settings. Lower the peak pressure first to eliminate any unintentional interruptions of the jet pulses, then lower the CV rate back to where it was before the circuit change.
8. Bring the humidifier out of its Wait mode by pressing the WAIT button after the Life Pulse has been restarted with the new cartridge/circuit; otherwise, the patient will receive relatively cold and dry gas.

**There are no alarms for low temperature or low water level when the humidifier is in the Wait mode.**

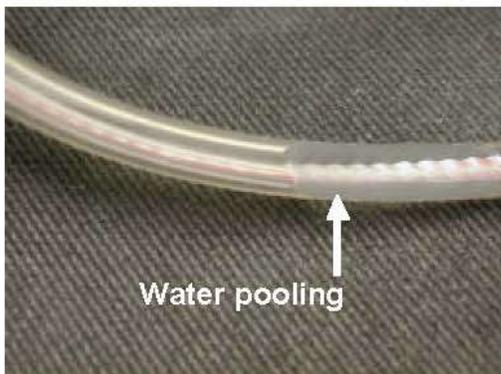
The circuit change is not complete until the water fills the cartridge, the water pump shuts off, and humidity appears in green portion of the circuit between the Patient Box and the LifePort.

On rare occasions, a defective cartridge might not fill, might over fill, or might not heat properly. It will then need to be replaced.

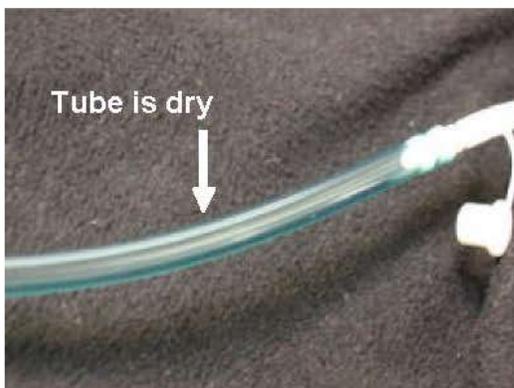
# IDENTIFYING PROPER HUMIDIFICATION



**Proper Humidification**  
Fine mist in green portion of circuit tubing



**Over Humidification**  
Water continuously pooling in clear portion of circuit tubing



**Under Humidification**  
Green portion of circuit tubing dry

It is important to identify proper humidification of the gas through the circuit. You can do this by observing the degree of mist in the green portion of the circuit tubing between the Patient Box and the LifePort adapter.

Proper humidification looks similar to the mist you would see when breathing on a mirror or against a car window on a cold winter day.

Excess humidification exhibits a collection of water pooling continuously in the clear portion of the circuit tubing between the cartridge and the Patient Box. The water may even begin to march into the patient's endotracheal tube. This condition can be alleviated by lowering the set CARTRIDGE temperature by 1-2<sup>o</sup> C.

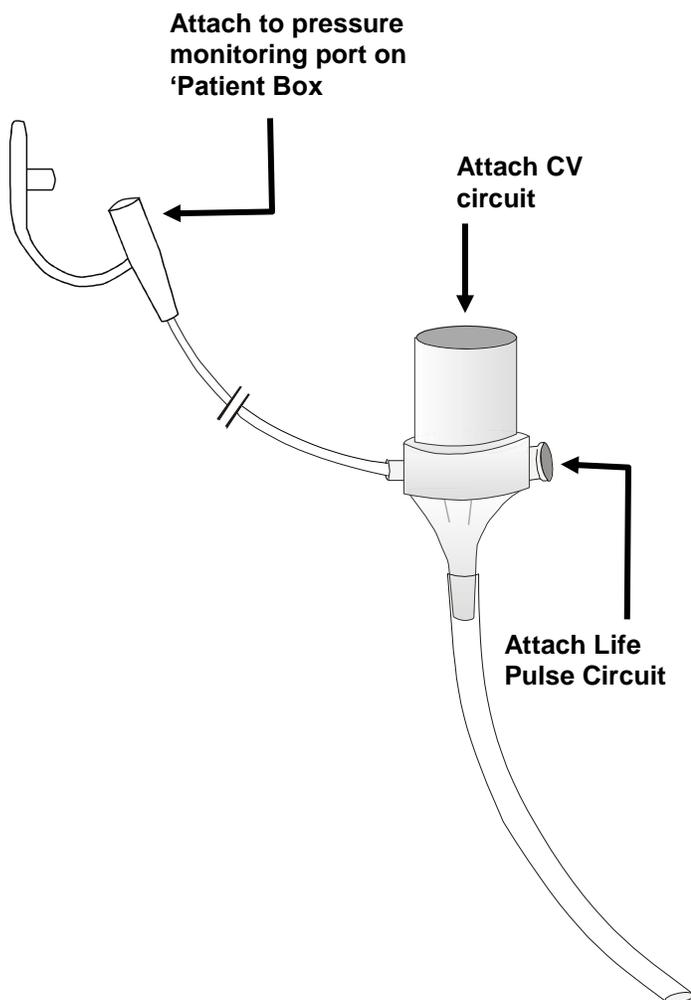
Insufficient humidification will be indicated by the green circuit tubing being dry.

Examples of proper, over, and under humidification are illustrated on the left.

It is important to see condensation in the green portion of the circuit between the Patient Box and the LifePort adapter. This condensation is an indication that the gas has reached 100% relative humidity.

### Objectives

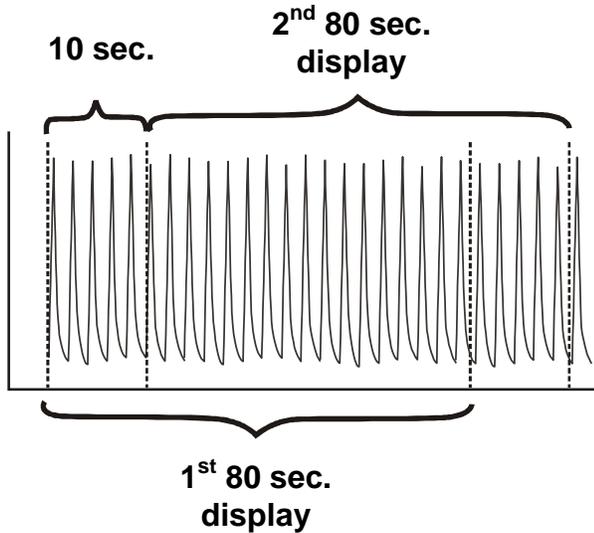
1. Learn how to determine initial settings for high-frequency ventilation.
2. Learn to balance the conventional and high frequency ventilators to achieve better blood gases while using less pressure.
3. Understand the changes in monitored PEEP level that can occur when initiating high-frequency ventilation.



The following procedures describe how to prepare the Life Pulse for start up:

1. Secure the caps on the LifePort adapter.
2. Replace the endotracheal tube adapter with the LifePort adapter once a successful test sequence has been completed, and **while the Life Pulse is still in the Standby mode.**
3. Reattach the patient to the conventional ventilator by connecting the conventional circuit to the 15-mm opening of the LifePort.
4. Once the patient has been stabilized on the conventional ventilator, make the LifePort adapter connections to the Patient Box and Life Pulse circuit **while the Life Pulse is in the Standby mode.**
5. Connect the pressure monitoring tube of the LifePort adapter to the Patient Box and connect the Life Pulse circuit to the Jet port on the side of the LifePort adapter.

# MEASURING & DISPLAYING PRESSURES



Once the pressure monitoring tube of the LifePort adapter has been connected to the Patient Box, the Life Pulse, **in its Standby mode**, will begin to monitor the pressures being delivered by the conventional ventilator or other high frequency ventilator and update them in the MONITOR section every 10 seconds.

It will take about a minute and a half for the MONITOR to display an accurate PIP, PEEP, and MAP being delivered by the conventional ventilator or HFOV.

In the Standby mode, the Life Pulse monitors and displays the airway pressures as if measured at the distal tip of the ET tube. These pressures may or may not be different from the pressures displayed on the conventional ventilator.

Remember that the conventional ventilator displays pressures measured proximally while the Life Pulse displays approximations of distal pressures. We recommend that start up decisions be based on the pressures displayed in the Life Pulse's MONITOR section.

## CHOOSING STARTING VALUES

The PIP setting chosen for initiation of high-frequency ventilation will depend on the PIP currently being monitored **by the Life Pulse in its Standby mode.**

The other initial high-frequency settings are usually left at the default values of a RATE of 420 breaths per minute and an ON Time of 0.02 seconds.

For larger patients the rate may need to be lowered to avoid gas trapping and inadvertent PEEP (240-360 bpm).

Generally, the more **pulmonary airleaks** are a concern, the lower you will set the background CV rate, PIP, and I-Time on the conventional ventilator. PEEP is a better way to control oxygenation in patients with airleaks.

The more **atelectasis** is a concern, the higher the background CV Rate, PEEP, and I-Time can be set.

Backgrounds CV rates greater than 10 bpm are almost never indicated.

**For more detailed information on choosing starting values, see the next few pages.**

# 6 STEPS TO START HFV

## SUMMARY OF SIX STEPS TO START-UP

1. Select the starting HFV PIP value.
2. Press the ENTER button to start the Life Pulse.
3. If necessary, lower PIP on the conventional ventilator to prevent interruption of high-frequency pulses.
4. Lower the conventional ventilator rate to CPAP to 3 breaths for air leak syndromes, 3 to 10 breaths for RDS.
5. If necessary, adjust PEEP setting: e.g., higher to improve atelectasis and oxygenation, lower if FiO<sub>2</sub> is lower than 30% and oxygenation is appropriate.
6. After settings stabilize, if a MAP alarm occurs, press the RESET button to enable the Life Pulse to recalculate correct alarm limits around the NEW settings.

### 1. Select Starting PIP Value

### 2. Press ENTER

Initiation of high-frequency ventilation involves six steps:

1. Once the monitored pressures are stable, select a starting PIP specific to the patient's pathophysiology. Input the chosen value by using the increase or decrease arrow next to the NEW PIP display in the CONTROLS section.
2. After selecting the NEW settings press the ENTER button to begin high-frequency ventilation.

As the Life Pulse begins to operate, note that the monitored values return to zero and new average values accumulate based on the new conditions.

## 6 STEPS TO START HFV (cont.)

The Life Pulse may pause every time the conventional ventilator delivers a breath. These interruptions may be heard, or seen by observing the JET VALVE ON/OFF lights.

The interruptions in the Jet pulses are caused by the delivery of conventional breaths at pressures higher than the PIP that has been requested by the operator and entered as the NOW PIP.

Except in cases of extremely poor lung compliance, it is usually best to allow the high-frequency pulses to continue uninterrupted by lowering the conventional PIP.

### 3. Lower Conventional PIP

3. If desired, lower the conventional PIP by slowly turning down the PIP knob to just below the threshold of interruptions; it may need to be lowered even more when treating infants with pulmonary airleaks.

### 4. Lower Conventional Rate

4. Lower the rate of the conventional ventilator to 0 -5 breaths per minute once the conventional PIP is set properly.

A conventional ventilator rate of zero (CPAP) to 4 breaths per minute may be used in cases of pulmonary air leak.

If oxygenation is still a concern after optimizing PEEP, provide ample opportunity for the recruitment of collapsed alveoli by adjusting CV PIP, I-TIME, or by providing up to 10 conventional breaths per minute. Lower the CV support (e.g., lower the rate to 1-3 bpm) once collapsed alveoli are recruited and stabilize them with adequate PEEP.

If both problems are of equal concern after PEEP has been optimized, start with the lowest number of CV breaths possible and modest CV PIP and I-TIME settings.

## 6 STEPS TO START HFV (cont.)

### 5. Readjust PEEP

Once high-frequency ventilation is initiated, the displayed PEEP may be slightly different than what is desired. Although PEEP is controlled by the conventional ventilator, high-frequency ventilation may cause it to rise or fall.

5. Adjust the conventional ventilator PEEP knob and/or flow rate to bring it to the level desired. Remember that average values are displayed, so give the Life Pulse 20 seconds between adjustments to indicate the true PEEP value.

Be aware of significant changes in Servo and mean airway pressure (MAP) that may occur when manipulating the conventional ventilator settings. For example, a pressure change of 2 cm H<sub>2</sub>O in the PEEP setting will cause a change of about 2 cm H<sub>2</sub>O in the MAP.

### 6. Press RESET

6. If changing PEEP produces a MAP or SERVO PRESS alarm, press the RESET button to accommodate the change. Or, the limits may be changed manually.

Pressing the RESET button allows the limits around SERVO PRESS and MAP to be recalculated and new alarm limits to be set.

The READY light will turn off when the RESET button is pressed. As soon as monitored values have been stable for 20 seconds, new limits will be set and the READY light will illuminate.

**Always wait until the READY light is ON before leaving the patient's bedside.**

# PATIENT MANAGEMENT

## Objectives

1. Understand the advantages for patient management of using a conventional ventilator in tandem with the high-frequency ventilator.
2. Understand the techniques for improving oxygenation and ventilation.
3. Comprehend the relationship between  $\Delta P$  and tidal volume.

### CLINICAL OBJECTIVES

Oxygenation Concerns → Conventional Ventilator

Ventilation & High Pressure Concerns → Life Pulse Ventilator

Managing patients on high-frequency ventilation is similar to managing patients on a conventional ventilator.

The main distinction with the Life Pulse is that typically less pressure and much smaller tidal volumes are used to manage the patient.

The conventional ventilator settings will be manipulated most often when oxygenation of the patient is of primary concern.

The Life Pulse settings will be manipulated most often when ventilation ( $\text{CO}_2$  removal) and/or the consequences of using high airway pressures (e.g., pulmonary air leaks) are of greatest concern.

# OXYGENATION

The main choices for improving oxygenation require increasing mean airway pressure by elevating the:

- **CV PEEP**
- **CV RATE**
- **CV PIP**
- **CV I-Time**

High-frequency PIP and rate would be secondary considerations. Raising high-frequency On-Time has rarely been shown to be effective in clinical trials.

The choices for improving oxygenation due to atelectasis are:

**1. Increase PEEP**

- Increases in PEEP are meant to stabilize alveoli.

PEEP changes are made with the conventional ventilator since the Life Pulse has no PEEP control. However, the PEEP adjustment will be displayed on the Life Pulse in the MONITOR, PEEP display.

**2. Increase CV Rate**

- Increase background rate from the conventional ventilator. Do not exceed 10 bpm on the background rate. If more CV breaths are needed to oxygenate, it may be an indication that the PEEP is too low.

**2. Increase CV Rate**

Always optimize PEEP before increasing CV Rate, PIP, or I-time.

- Increase the PIP delivered with the background conventional breaths. Increases in CV PIP are meant to reach the critical opening pressure required to inflate collapsed alveoli.

Adequate PEEP levels are essential for avoiding derecruitment between conventional breaths.

# OXYGENATION

(cont.)

## 4. Increase CV I-Time

- Increase I-Time, in combination with adequate levels of PEEP and PIP, to improve atelectasis.

Consider carefully the combined effect of PIP and I-Time increases. Increasing I-Time when CV PIP is set at high levels increases the risks of causing lung injury.

- If other approaches to oxygenation have failed or are contrary to the patient's pathophysiology, increase the Life Pulse PIP by 2 cm H<sub>2</sub>O at a time until the desired response has been achieved.

Increasing HFV PIP too high may result in hyperventilation and hypocarbia which, in preterm infants may increase the risk of cerebral injuries. Concomitant increases in PEEP may help maintain an appropriate tidal volume and reduce this risk.

- If necessary, the conventional ventilator PIP can be increased along with the Life Pulse peak pressure except in severe cases of air leak. However, **the CV PIP should not be raised if it is at an adequate level to reach the critical opening pressure of the alveoli.**

Remember to keep the conventional PIP below the Life Pulse's peak pressure to avoid interrupting the high-frequency pulses.

Additional possibilities for increasing mean airway pressure are available, but they have not been studied in prospective clinical trials. Increasing high-frequency rate by 50 or 60 breaths per minute at a time has been helpful in some cases, especially in smaller infants.

If the high-frequency rate is increased, be sure to watch the PEEP level. Inadvertent PEEP may develop as the I:E ratio is shortened.

# OXYGENATION

## Overexpanded Lungs

**EXCEPTION!**  
**Overexpanded Lungs**

There is one major exception to this strategy. This exception arises when the patient on conventional ventilation has grossly overexpanded lungs.

If overexpansion is observed on X-ray, the lungs will need to deflate considerably before any improvements in oxygenation will result.

To accomplish this deflation, set the conventional ventilator rate near zero when starting the Life Pulse.

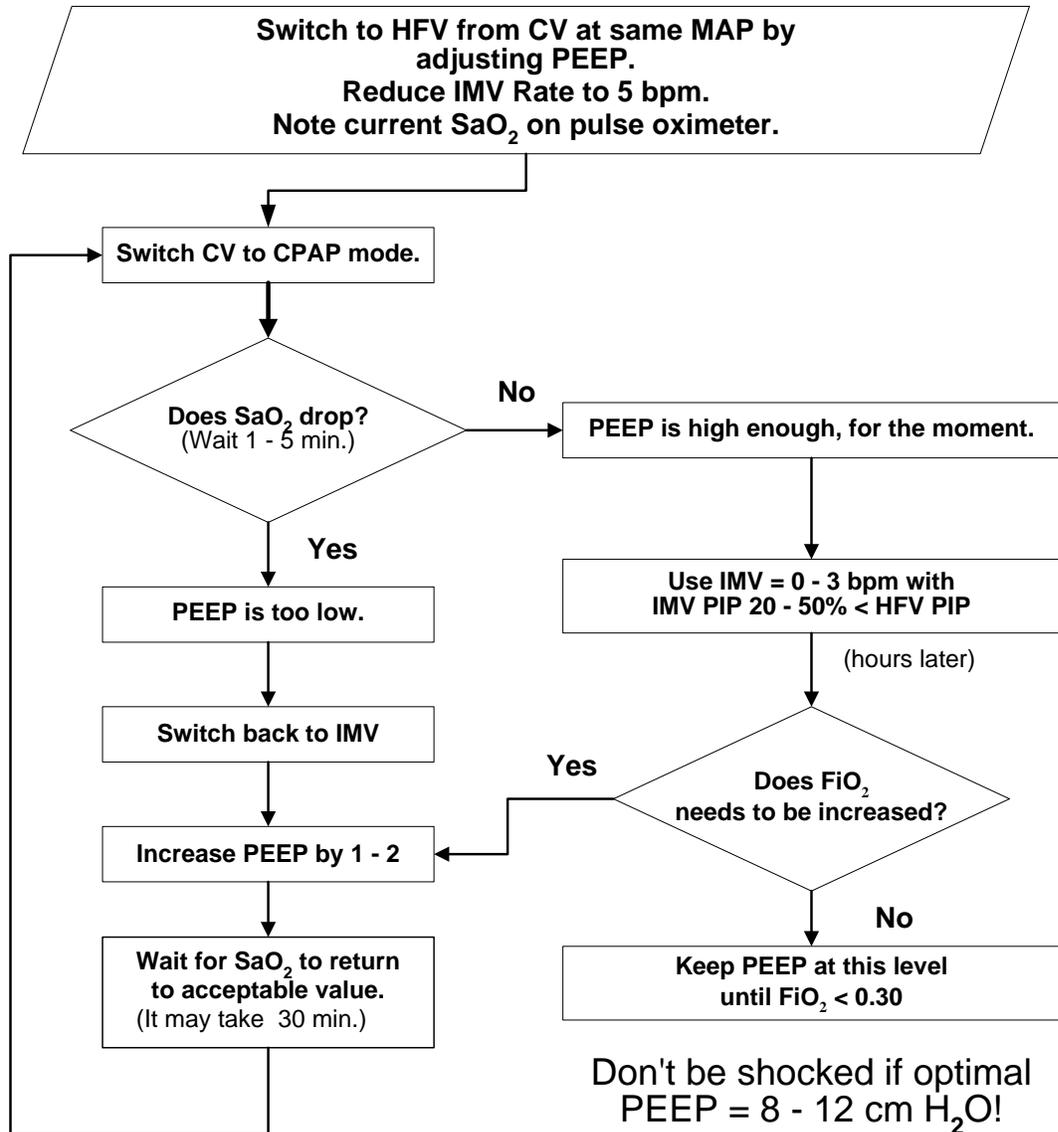
In most cases, **DO NOT DECREASE PEEP**. Overexpanded lungs are usually a result of gas trapping, not excessive PEEP. Decreasing CV support (Rate, PIP, and I-Time) is usually a more effective strategy. PEEP must be maintained, or even increased, when the CV rate is very low to prevent atelectasis and maintain oxygenation.

However, beware that if the patient initially responds well to this strategy, poor oxygenation may result some time later due to atelectasis. You must be ready to treat that condition as outlined above.

A strategy for identifying optimal PEEP is demonstrated in the flow chart on the next page. It is always important to optimize PEEP regardless of what pathophysiology is being treated.

# FINDING OPTIMAL PEEP

## Finding Optimal PEEP during HFV \*



\* when switching from CV to HFV.

*Warnings:* Lowering PEEP may improve SaO<sub>2</sub> in some cases.

Optimal PEEP may be lower in patients with active air leaks or hemodynamic problems.

Using IMV with high PEEP is hazardous. Do not assume high PEEP causes over-expansion.

# VENTILATION

Manipulating the patient's arterial  $PCO_2$  is one of the easier tasks when using the Life Pulse. Studies have shown that ventilation ( $CO_2$  elimination) during high-frequency ventilation is proportional to the tidal volume squared ( $V_T^2$ ).

Tidal volume on the Life Pulse is roughly proportional to delta P ( $\Delta P$ ), the arithmetic difference between PIP and PEEP. Thus, small changes in PIP or PEEP can produce significant changes in a patient's  $PCO_2$ .

The main choices for improving ventilation require increasing minute ventilation by changing:

- **HFV PIP**
  - **PEEP**
  - **HFV Rate**
- If the patient's  $PO_2$  is acceptable, but his  $PCO_2$  is too high, increase high-frequency PIP by 1 to 2 cm  $H_2O$  at a time.
  - If the patient's  $PO_2$  and  $PCO_2$  are both unacceptable, increasing PIP may address both problems at once.

## 1. Increase HFV PIP

When PEEP is increased, oxygenation may improve. However, increasing PEEP without a corresponding increase in HFV PIP reduces tidal volume and may result in some degree of  $CO_2$  retention.

The PIP must be increased by an equal amount in order to keep the delta P ( $\Delta P$ ) the same and maintain tidal volume and adequate ventilation.

# VENTILATION (cont.)

## 2. Decrease PEEP

- If the primary concern is air leaks or cardiac compromise and oxygenation is acceptable, lower PEEP in order to increase  $\Delta P$  (i.e., tidal volume) and increase ventilation.

Be careful not to compromise oxygenation when lowering PEEP.

## 3. Increase HFV Rate

- Increase the high-frequency rate by 40 to 80 breaths per minute at a time to improve ventilation without further increasing PIP.

Increasing high-frequency rate is much less effective than increasing delta P ( $\Delta P$ ) for reducing  $PCO_2$ .

Changes in CV Rate, PIP, and, to a lesser degree, I-Time may also effect HFV minute ventilation. Raising CV Rate or PIP seldom improves ventilation, but it may be helpful in extreme cases if HFV is not interrupted.

## 4. Hyperventilation

- The main choices for raising  $PCO_2$  are, of course, doing the opposite of the above suggestions for lowering  $PCO_2$ .

Decreasing HFV PIP is the most effective way to increase  $PCO_2$ . However, the concomitant drop in mean airway pressure may cause  $PO_2$  to fall. Thus, it is very important to raise PEEP in such cases to maintain adequate mean airway pressure.

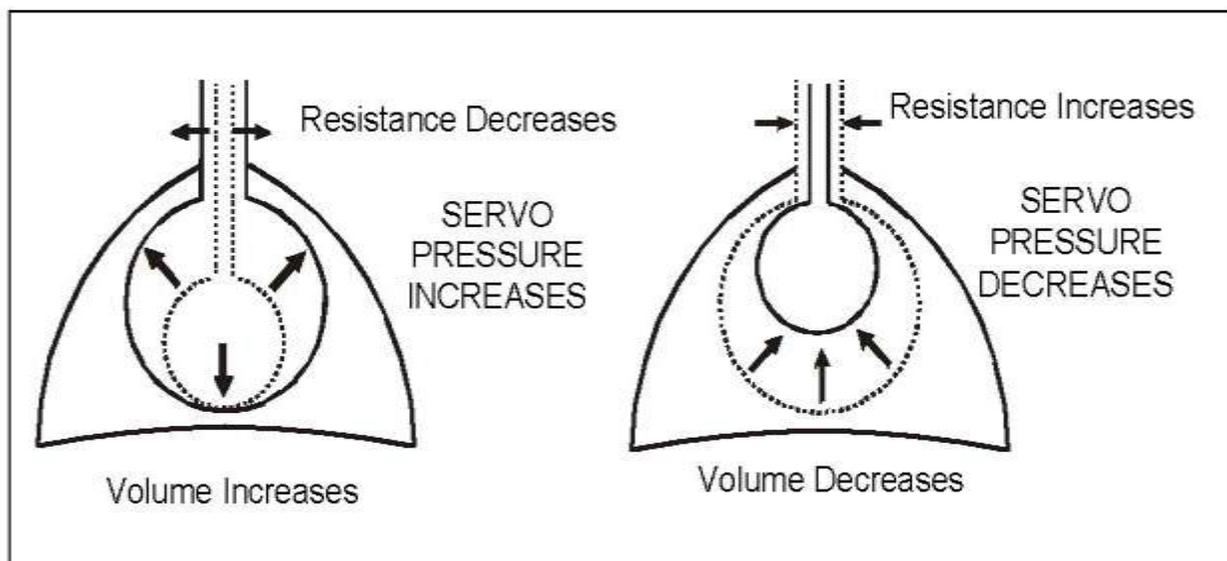
Reducing HFV Rate will also increase  $PCO_2$  unless inadvertent PEEP is present. If monitored PEEP falls when HFV Rate is dropped, PEEP may need to be increased to maintain adequate oxygenation.

Do not hesitate to use the minimum Life Pulse HFV Rate of 240 bpm when indicated for hyperinflation. The Life Pulse can provide adequate ventilation over its entire range of HFV Rates (240 - 660 bpm).

# UNDERSTANDING SERVO PRESSURE

Understanding Servo Pressure, what it is, why it changes, how it changes, can indicate when a patient's condition is improving or worsening. The diagram and text below may be helpful in understanding Servo Pressure and how it can help manage patients.

- Servo Pressure = driving pressure that automatically regulates flow.
- Servo Pressure changes as lung volume or mechanics change



Servo Pressure changes: early warning of changes in patient condition.

**SERVO PRESSURE INCREASES WITH:**

- Improving compliance or resistance
- Leak around ETT
- Tubing leak

**SERVO PRESSURE DECREASES WITH:**

- Worsening compliance or resistance
- Obstructed ETT
- Tension Pneumothorax
- Right mainstem intubation
- Patient needs suctioning

Charting Servo Pressure simplifies patient management decisions.

# SUCTIONING THE PATIENT

## Objectives

1. Learn three methods of suctioning a patient while on high-frequency ventilation, which technique is preferred, and when to use which alternative.
2. Be ready for problems that may possibly be encountered when using each suctioning method.

### SUCTIONING 3 Techniques

1. Suction with Life Pulse in Standby mode
2. Suction with Life Pulse running
3. Suction with in-line suction system

High-frequency ventilation may mobilize and help remove secretions.

Be prepared to suction soon after starting the Life Pulse on a patient.

Suctioning may need to be performed more frequently in the first 4 to 6 hours. Suctioning frequency may then subside.

Suctioning the patient's airway may be accomplished by either of three methods:

- with the Life Pulse in the Standby mode
- with the Life Pulse running
- using an in-line suction catheter system

# SUCTION PROCEDURE #1

## Suctioning in the Life Pulse's STANDBY Mode

The first technique for suctioning the patient is the easiest to learn because the procedure is similar to suctioning during conventional ventilation.

1. Place the Life Pulse into the Standby mode.
2. Suction as usual.
2. Press the **ENTER** button after reattaching the conventional ventilator circuit, when the suction procedure is complete.

## SUCTION PROCEDURE #2

### Suctioning with the Life Pulse Running

#### SUCTIONING CHECKLIST

- READY light **must** be on!
- Instill into Jet port then reconnect Life Pulse circuit.
- One person disconnect CV circuit from LifePort.
- Second person **applies suction going into and out of the ET Tube.**
- Reconnect CV circuit to LifePort.
- Press SILENCE button, if necessary

The second technique requires that suction be applied in the endotracheal tube throughout the introduction and withdrawal of the suction catheter:

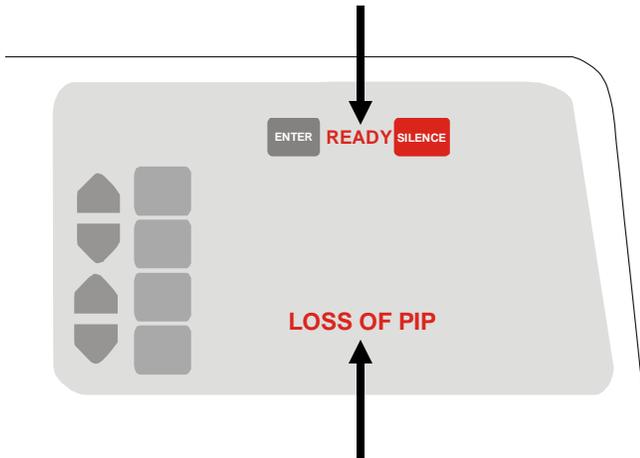
1. First, **make sure the Life Pulse's READY light is ON** before beginning the suction procedure.
2. Press the alarm SILENCE buttons on both ventilators.
3. With the Life Pulse running, disconnect the Life Pulse circuit from the Jet port of the LifePort adapter.
4. Instill irrigation fluid into the Jet port.
5. Reattach the Life Pulse circuit to the Jet port to "jet" the fluid into the patient's airways.
6. One person may disconnect the conventional circuit from the 15-mm connection of the LifePort while a second person prepares to introduce the suction catheter.
7. Introduce the catheter with suction applied.

This procedure allows the Life Pulse to continue ventilating the patient with fewer interruptions. If suction is not applied while advancing the suction catheter, the catheter creates an obstruction and the Life Pulse will pause to protect the patient; the Life Pulse will not deliver gas if the exhalation path is obstructed by the suction catheter.

Suctioning all the way into the ET tube **and** all the way back out allows the patient to receive some jet ventilation throughout the suction procedure.

## SUCTION PROCEDURE #2 (cont.)

**If suctioning with the Life Pulse Running,  
MAKE SURE THE READY LIGHT IS ON!**



**If a LOSS OF PIP alarm occurs with the  
READY light on, the Servo Pressure locks  
to protect the patient.**

A LOSS OF PIP alarm usually occurs when suctioning with the Life Pulse running. As long as the Life Pulse is in the READY condition, the Servo Pressure will lock at or near its operating level and the patient will continue to receive appropriate ventilation even though the displayed PIP and PEEP may fluctuate.

8. Reconnect the conventional ventilator when finished.
9. Provide a few manual breaths with the conventional ventilator to help the patient recover from the procedure.
10. Press the SILENCE button to stop audible alarm.
11. If necessary, press the ENTER button to clear all alarms and reestablish appropriate ventilation and new alarm settings.

If pressure fluctuations continue after the suctioning procedure, it may be necessary to press the ENTER button again. This action will activate the Jet's purge system to clear the pressure monitoring tubing of fluids.

If problems persist with pressure fluctuations and the CANNOT MEET PIP alarm is displayed, it may be necessary to suction again to remove secretions from the distal tip of the ET tube.

## SUCTION PROCEDURE #3

### Suctioning with an In-Line Suction System

#### SUCTIONING CHECKLIST

- Select an in-line suction system compatible with the LifePort adapter
- Select an in-line suction system with a catheter that is straight for the first few inches
- Suction according to procedure 1 or 2 described earlier in this section
- Call the Bunnell Hotline for more information or assistance.

The third technique may be used in conjunction with techniques 1 and 2. The key to success using this procedure is to choose a compatible in-line suction system.

The two most important factors in choosing an in-line system are:

- how the system connects to the LifePort adapter

An in-line suction system that uses a special adapter which replaces the conventional ET tube adapter cannot be used with the Life Pulse. The Life Pulse requires the LifePort adapter in order to operate. For example, The Ballard “Neonatal Elbow” system can be use with the Life Pulse; the Ballard “Neonatal ‘Y’ ” system cannot.

- if the suction catheter is straight for the first few inches at its tip

A straight tip on the in-line suction catheter ensures a “straight shot” into the endotracheal tube. A curved suction catheter may dead-end against the inner wall of the LifePort adapter making it difficult to advance the catheter down the ET tube.

Once a compatible inline suction system has been selected, it can be used according to the procedures outlined in procedures 1 and 2 described earlier in this section.

**Objectives:**

1. Recognize the indications for weaning from the Life Pulse.
2. Know the various options for weaning and the advantages of each.

As the patient improves, he will eventually need to be weaned from the Life Pulse. The goal in most cases will be to wean the patient back to conventional ventilation at much less support than the patient was on before beginning high-frequency ventilation.

However, the Life Pulse may be left on the patient while he is weaned directly to CPAP, a nasal cannula, or an oxygen hood.

Below is a brief summary of weaning guidelines:

**GENERAL GUIDELINES FOR WEANING**

- Decrease Minute Ventilation and MAP slowly by lowering PIP on the Life Pulse and the conventional ventilator.
- Lower  $F_{iO_2}$  gradually to around 30%.
- Continue decreasing PIP as blood gases allow, weaning slowly (1-2 cm  $H_2O$  of PIP), unless hyperventilation is occurring, in which case PIP should be weaned faster.
- As the PIP is lowered into the teens, begin to allow the conventional ventilator breaths to interrupt the high-frequency pulses.
- As the high-frequency PIP continues to be decreased, increase the conventional rate as needed to achieve good blood gases.
- Place the Life Pulse into the Standby mode.

# WEANING

(cont.)

**Wean SLOWLY!**

- **Wean slowly:** The fundamental rule in weaning is to WEAN SLOWLY, to wean as slowly as the patient allows. The Life Pulse is a very gentle form of ventilation, much more so than conventional ventilation. Therefore, weaning a patient back to conventional ventilation too soon is ill-advised.

**Find Optimal MAP**

- **Find Optimal MAP:** During patient management, the MAP should be kept as low as the patient's pathophysiology allows without compromising oxygenation.

As the patient's condition improves, blood gases will indicate that pressures can be weaned.

**Lower HFV PIP**

- **Lower Life Pulse PIP:** As weaning begins in earnest, reduce PIP in increments of only 1 to 2 cm H<sub>2</sub>O unless PCO<sub>2</sub> is below 35 torr.

Small changes in tidal volume have very dramatic results during high-frequency ventilation whether you are increasing or decreasing support. Lower the conventional PIP just enough to avoid interruptions of the high-frequency pulses when these brief interruptions begin to occur.

**Adjust PEEP if necessary**

- **Adjust PEEP:** The PEEP may be adjusted as necessary to maintain adequate PO<sub>2</sub>, alveolar inflation, and MAP (which may decrease as PIP is weaned). Do not worry about lowering PEEP until FiO<sub>2</sub> is .30 or less.

**Lower FiO<sub>2</sub>**

- **Lower FiO<sub>2</sub>:** Begin more aggressive weaning of FiO<sub>2</sub> when you are comfortable with the patient's MAP. Remember to adjust both blenders so the settings remain equal.

# WEANING (cont.)

**Resume Lowering HFV PIP**

- **Resume weaning PIP:** Do so as tolerated.

If the patient begins to deteriorate with further reductions in PIP, the pressure may be near a mean airway pressure threshold. In this case, cease weaning and consider raising PEEP to stabilize the lungs. Resume weaning when the patient is ready as determined by blood gases and clinical observation. If possible, you may continue weaning  $\text{FiO}_2$  during the interim.

**Allow Jet Pulse Interruptions**

- **Allow Jet Pulse Interruptions:** When the high-frequency PIP has been lowered into the mid-teens, allow the conventional ventilator breaths to interrupt the high-frequency pulses (i.e. don't lower CV PIP further).

**Begin CV Trial by Placing Life Pulse in STANDBY**

- **Add CV Support:** provide more CV support by increasing the conventional ventilator's IMV rate as high-frequency PIP is weaned.

**Add CV Support as Necessary**

Once the high-frequency PIP is down to approximately 15 cm  $\text{H}_2\text{O}$  or less, and the conventional rate has been increased to about 15-20 bpm, the patient's chest rise will be much more a result of the conventional breaths than the high-frequency pulses.

- **Attempt CV Trial:** Place the Life Pulse into the Standby mode to begin a trial of conventional ventilation only. The CV PIP should not have to be raised above 20 cm  $\text{H}_2\text{O}$ . If this is necessary, the trial has failed. Return to HFV.

- If the patient is stable on conventional ventilation, disconnect and cap the Jet port and the pressure monitoring tube of the LifePort adapter.

**Weaning Directly to CPAP or Nasal CPAP**

- **Weaning to Nasal CPAP:** If the patient is stable on low Life Pulse and background CV settings, and the patient is breathing on his own, try the patient on CPAP. If tolerated, you may want to extubate the patient to nasal CPAP.

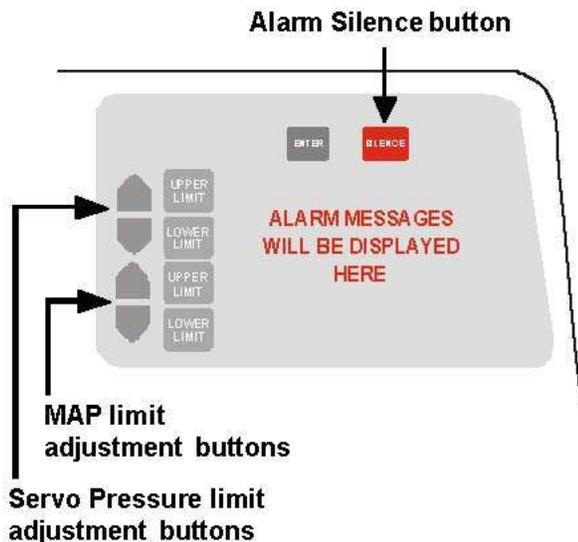
- Remove the Life Pulse for cleaning and preparation for the next patient.

# Chapter 10

## VENTILATOR ALARMS

### Objectives

1. Understand how the High and Low alarm limits are set for the Servo Pressure and Mean Airway Pressure.
2. Learn how and when to change the High and Low alarm limits.
3. Know the possible causes of the six types of alarm messages and how to troubleshoot and correct them.



The Life Pulse alarm system alerts the operator, both audibly and visually, to changes in the ventilator or the patient. The alarm statements are not visible until they are lit.

The **ALARMS** area has three key features:

- upper and lower alarm limits for Servo and Mean Airway Pressure (MAP);
- alarm messages for various potentially hazardous conditions, and;
- an alarm SILENCE button.

Both the upper and lower alarm limits are set automatically and can be adjusted manually. After the ENTER button has been pressed, the Servo Pressure rises to bring the monitored PIP up to the NOW PIP setting.

The alarm limits are set automatically when the READY light comes on indicating that the monitored PIP has come to within  $\pm 1.5$  cm H<sub>2</sub>O of the NOW PIP and has stabilized there for at least 20 seconds.

The instant the READY light comes on, the limits around the current Servo Pressure are set and vary according to the size of the patient; wider limits are set for larger patients and tighter limits for smaller patients.

### READY Light ON

1. Monitored PIP  $\pm 1.5$  cm H<sub>2</sub>O of set NOW PIP for 20 Seconds.
2. SERVO PRESSURE alarm limits vary according to size of patient.
3. MAP alarms set  $\pm 1.5$  cm H<sub>2</sub>O.

# ALARM LIMITS

The limits around the current mean airway pressure (MAP) are set at  $\pm 1.5$  cm H<sub>2</sub>O.

Press the various limit buttons any time after the READY light is lit to observe where the limits have been set.

If the READY light is not lit then the limits have not yet been set, and the SERVO PRESS and MAP displays will not change when you press one of the limit buttons.

To change the limits and make them tighter or wider in any combination, press the button for the particular limit, hold it down, and press either the increase or decrease button next to it.

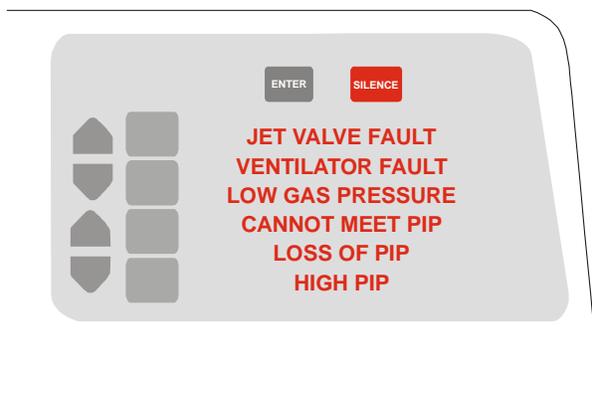
The other alarms that are available with the Life Pulse are illuminated only to indicate changing or potentially threatening conditions.

While in the Standby mode, press the TEST button to observe a display of these alarms.

***Do NOT perform the Test while a patient is connected to the Life Pulse.***

Alarm messages include:

- JET VALVE FAULT
- VENTILATOR FAULT
- LOW GAS PRESSURE
- CANNOT MEET PIP
- LOSS OF PIP
- HIGH PIP



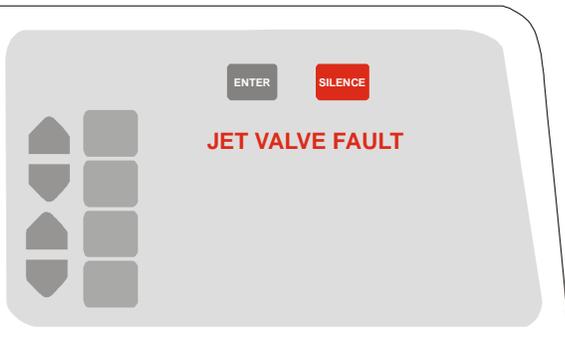
# JET VALVE FAULT

## JET VALVE FAULT

A **JET VALVE FAULT** alarm implies that the pinch valve is out of synchrony with the electrical drive signal. A JET VALVE FAULT alarm will appear in the ALARMS section and the Life Pulse and Patient Box will continue running.

This alarm is extremely rare; if it occurs call the **Bunnell Hotline at 1-800-800-4358** for troubleshooting support. The JET VALVE FAULT alarm only applies to electrical failures. If the pinch valve fails mechanically, it will stop cycling.

The following precautions should be followed if the “WhisperJet” Patient Box (Cat # 312) pinch valve stops cycling while on a patient.



### In the **READY** condition:

1. A Loss of PIP alarm will be activated; check for chest vibration.
2. **Do not press the Enter or Reset buttons.**
3. If chest is vibrating, do normal troubleshooting for Loss of PIP alarm (see Operator’s Manual).
4. If chest is not vibrating, check the pinch valve.
5. **If pinch valve is NOT CYCLING, press the STANDBY button to dump the Servo Pressure and change out the “WhisperJet” Patient Box.**
6. Call Bunnell Hotline to report stoppage, get RA#, and send “WhisperJet” Patient Box to Bunnell for service.

### In the **Non-READY** condition:

1. A Loss of PIP alarm will be activated; verify pinch valve is cycling.
2. **Do not press the Enter or Reset buttons.**
3. If pinch valve is cycling, do normal troubleshooting for a Loss of PIP alarm (see Operator’s Manual).
4. **If pinch valve is NOT CYCLING, press the STANDBY button to dump Servo Pressure and change out “WhisperJet” Patient Box.**
5. Call Bunnell Hotline to report stoppage, get RA#, and send “WhisperJet” Patient Box to Bunnell for service.

# VENTILATOR FAULT: HFV CONTINUES RUNNING

## VENTILATOR FAULT

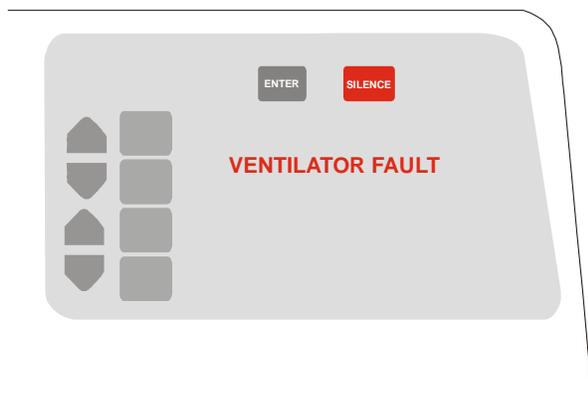
A **VENTILATOR FAULT** message may or may not be serious. If the Life Pulse has a serious Ventilator Fault, it will automatically put itself in the **STANDBY** mode with the audible alarm sounding.

Ventilator Fault alarms that place the Life Pulse in Standby will display a code number in the **ON/OFF** display window of the **CONTROLS** section to let the operator or service rep know where the fault occurred.

If the Life Pulse continues to run with the **VENTILATOR FAULT** message, possible causes are:

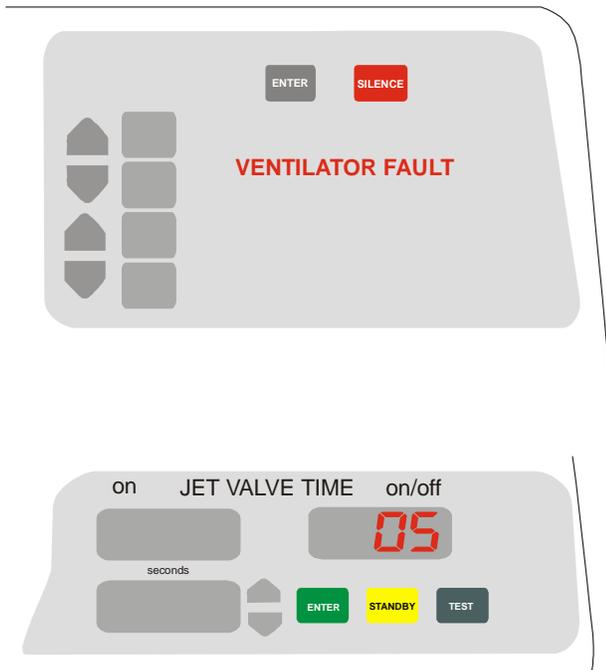
- One of the ends of the purge tube has become disconnected, either at the **PURGE** connector on the front panel, or at the **FROM PURGE** connector on the Patient Box.
- The purge tube is kinked or obstructed.

In any case, with the Life Pulse in its Ready condition, the Life Pulse will continue operating because the purge function is not critical for supporting the patient.



## VENTILATOR FAULT: HFV STOPS RUNNING

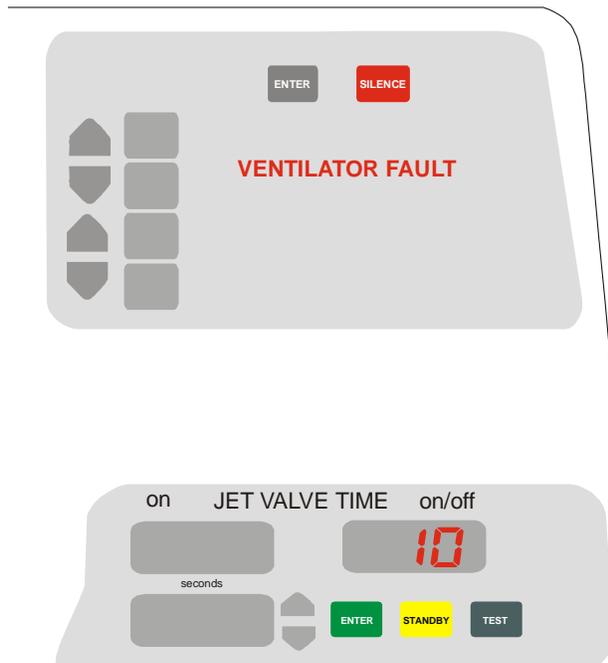
If the **VENTILATOR FAULT** places the Life Pulse into Standby mode and a code number appears in the ON/OFF window, take the following steps to determine if the alarm is true:



1. Disconnect the patient from the Life Pulse.
2. Provide ventilatory support to the patient using the conventional ventilator.
3. Turn off the power to the Life Pulse for at least three minutes.
4. Turn on the power, attach a test lung to a Life Pulse circuit, and perform an internal test by pressing the **TEST** button.
5. Perform an operational check of the Life Pulse on a test lung with the 15 mm LifePort connector open to the room.
6. If the Life Pulse reaches the set pressure, the **READY** light illuminates, and a **VENT FAULT** alarm doesn't occur, it is safe to resume ventilation.
7. If the Test procedure fails, call the **Bunnell Hotline** at **1-800-800-4358**.

# VENTILATOR FAULT CODE 10

## VENTILATOR FAULT Code 10



There is one Ventilator Fault that may cause the Life Pulse to revert to the STANDBY mode **but** is immediately recoverable.

If the Servo Pressure rises 3.4 psi (23.44 kPa) above the level necessary to have met the READY condition, the Life Pulse will revert to STANDBY mode with a **VENTILATOR FAULT** and a code **10** displayed in the ON/OFF ratio display in the CONTROL section.

After the condition that caused the alarm (e.g., a kinked pressure monitoring tube) is corrected, press the ENTER button and the Life Pulse will resume normal operation.

If the VENTILATOR FAULT 10 was caused by a problem not immediately correctable (e.g., a faulty Servo Pressure control valve), the Life Pulse, after the ENTER button is pressed, will immediately enter the STANDBY mode and display another VENTILATOR FAULT 10.

If necessary, call the **Bunnell Hotline** at **1-800-800-4358**.

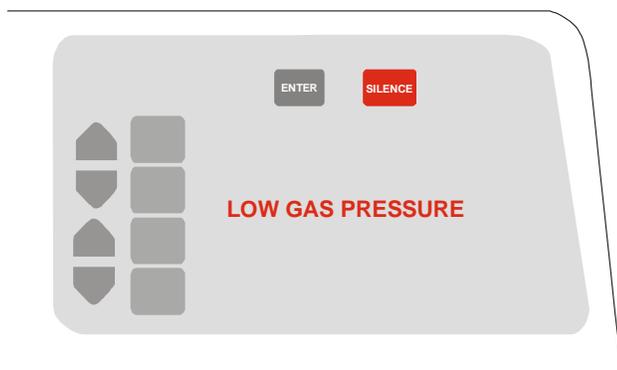
## LOW GAS PRESSURE

### LOW GAS PRESSURE

A **LOW GAS PRESS** alarm indicates that the gas supply to the Life Pulse has fallen to a pressure less than 30 psi (206.85 kPa). This alarm could indicate that:

- You have a leak in one of the gas supply lines, the blender, or a failure in the hospital's gas supply system, or
- The gas pressure switch in the Life Pulse is faulty. The Life Pulse will otherwise function properly but will display a continuous **LOW GAS PRESS** alarm.

If necessary, call the **Bunnell Hotline** at **1-800-800-4358**



# CANNOT MEET PIP

## CANNOT MEET PIP



## CANNOT MEET PIP Causes

1. Ready condition not met within 3 minutes
2. Servo Pressure reaches 20 psi (137.90 kPa) before the Ready condition is met

A **CANNOT MEET PIP** alarm means one of two things:

- the Life Pulse has been unable to meet the Ready condition within 3 minutes of pressing the RESET or ENTER button; or,
- the Servo Pressure has risen to 20 psi (137.90 kPa) and the Ready condition has not been met.

The first criteria would be met if conditions keep changing after the RESET or ENTER button is pressed. An unstable monitored PIP makes it difficult for the Life Pulse to meet the criteria necessary to enter the Ready condition.

For example, a patient who is taking vigorous spontaneous breaths may initiate this alarm. The alarm may be alerting you that the patient needs comforting, attention, or possibly sedation.

This condition can be simulated with a test lung by periodically creating leaks after pressing the ENTER button. The CANNOT MEET PIP alarm will occur after 3 minutes.

The second criteria may be met with a relatively large patient on the Life Pulse, or if large leaks are present somewhere in the system. This condition can be simulated by using a test lung with a large air leak.

In either case, the Life Pulse does not give up trying to meet the Ready condition. This alarm is simply informing you that the Life Pulse is taking longer than usual to meet the Ready condition.

If necessary, call the **Bunnell Hotline** at **1-800-800-4358**

# LOSS OF PIP

## LOSS OF PIP

The **LOSS OF PIP** alarm implies an extubation or a disconnected, obstructed, or kinked tube. The alarm is initiated by one of the following criteria:

- The monitored PIP drops below 25% of the NOW PIP.
- The monitored PIP is less than 3 cm H<sub>2</sub>O.
- The monitored PIP and PEEP are within 2 cm H<sub>2</sub>O of each other.

The Life Pulse responds to a **LOSS OF PIP** alarm in the Non-READY condition as follows:

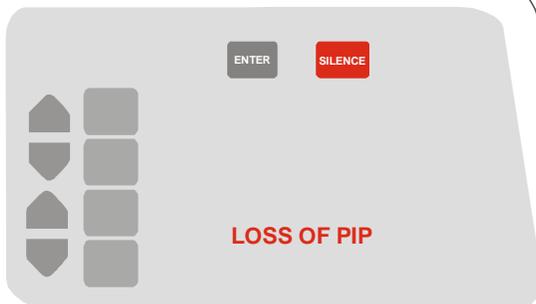
- The Servo valves close.
- The Servo Pressure and PIP will drop to or near zero.
- **The patient will not be receiving adequate ventilation!**

This response is designed to stop gas flow into the patient circuit during start-up, or when changing settings, if inadequate PIP is detected. It also prevents pressure spikes when the Life Pulse circuit is disconnected or kinked, then reconnected or unkinked while the READY light is off.

Gas flow is easily restarted by pressing the ENTER button.

If the **LOSS OF PIP** alarm occurs in the Ready condition, the Servo valves are designed to lock and allow the Life Pulse to continue to ventilate the patient with nearly constant tidal volumes.

You should NOT press the ENTER button if the Servo Pressure display is locked at or near the established operating level and the patient's level of ventilation is adequate. Eliminating the cause of **LOSS OF PIP** will eliminate the alarm condition.

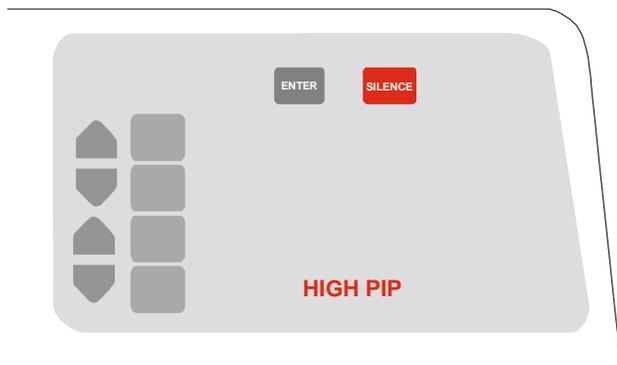


## LOSS OF PIP Causes

1. 25% drop in monitored PIP.
2. Monitored PIP < 3 cm H<sub>2</sub>O.
3. Monitored PIP and PEEP within 2 cm H<sub>2</sub>O.

If necessary, call the **Bunnell Hotline** at  
1-800-800-4358

## HIGH PIP



## HIGH PIP Causes

1. Pressure 5 cm > NOW PIP for 1 sec.
2. PIP 10 cm > NOW PIP for each breath over a 30-second period
3. Monitored PIP > NOW PIP by 30 cm for each breath during a 0.75 sec. period.
4. Instantaneous airway pressure > 65 cm H<sub>2</sub>O

The **HIGH PIP** alarm indicates one of the following conditions:

- the monitored pressure has exceeded the set NOW PIP by at least 5 cm H<sub>2</sub>O for 1 second;
- the PIP has consistently exceeded the NOW PIP by 10 cm H<sub>2</sub>O for all high-frequency breaths for the past 30 seconds; or,
- the monitored PIP for each breath during a 0.75 second period exceeds the set point by 30 cm H<sub>2</sub>O, or,
- Instantaneous airway pressure > 65 cm H<sub>2</sub>O

This alarm may be observed by pinching off the exhalation limb of the conventional circuit. Note that the Life Pulse Servo Pressure is “dumped” in this condition. Although it has no way of alleviating a condition caused by the conventional ventilator, the Life Pulse does ensure that it will not further aggravate the problem.

All of the alarm conditions described in this section are accompanied by an audible alarm. While the cause of the alarm is being evaluated, the beeping may be silenced by pressing the Alarm **SILENCE** button.

It may be necessary to review this section several times before becoming familiar with the conditions that trigger each alarm.

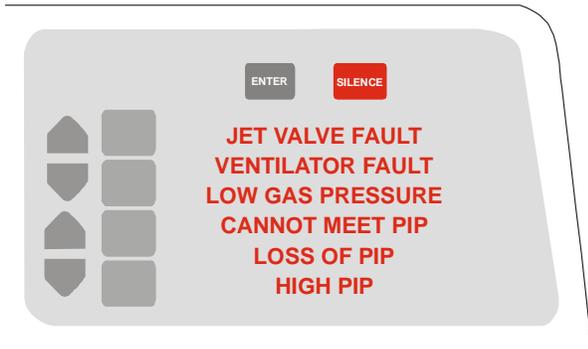
Remember, all alarms are important and should be responded to by the operator.

If necessary, call the **Bunnell Hotline** at **1-800-800-4358**.

# INTERPRETING VENTILATOR ALARMS

## Objectives

1. Understand the usefulness of ventilator alarms.
2. Know the “Five Principles” of ventilator troubleshooting.



**ALARM DISPLAY**

This section discusses interpreting and correcting the ventilator alarms. It is beyond the scope of this manual to list all possible problems and their solutions.

Many ventilator problems and corrective actions have already been covered. A more comprehensive review is offered in the Operator’s and Service manuals. There are, however, a few general principles that can simplify Life Pulse troubleshooting.

Most of the necessary troubleshooting will be in response to alarms. Ventilator alarms alert the operator to changes in the patient or the Life Pulse. It is recommended that when a patient is on the Life Pulse the operator:

- pays particular attention to ventilator alarms; and,
- sets the alarm volume loud enough to present a sense of urgency when it sounds

There are at least five basic troubleshooting principles that, if followed, will help make working with patients on the Life Pulse easier.

# LOOK AT THE PATIENT

## 1. Look At The Patient

First, as with any ventilator, observe the patient. Whenever an alarm occurs, **LOOK AT THE PATIENT FIRST.**

- Is the patient's chest rise adequate?
- How is the patient's color?
- How is the patient's external monitoring?
- Is there an obvious disconnected tube near the patient?
- Has the Servo Pressure locked at or near its operating level? With the most common Life Pulse alarm, **LOSS OF PIP**, the Servo Pressure will lock and the patient will continue to receive a constant level of ventilation.

The cause of the alarm may then be determined without increasing conventional ventilator support or providing manual ventilation.

However, some alarm conditions may require the conventional ventilator settings to be increased to provide ventilation while an alarm condition is corrected, or the patient may need to be hand bagged.

# USE COMMON SENSE

## 2. Use Common Sense

Second, **USE COMMON SENSE**. There is no substitute for a skilled and alert therapist, nurse, or doctor who takes a logical approach to alarm interpretation.

- The Life Pulse's rhythmic sounds will become familiar to you. Learn to recognize when the sounds have changed.
- The displayed and monitored values should remain at consistent levels. Watch for changes in these levels and learn to understand what the changes mean.

For example, the Servo Pressure value reflects the gas flow and pressure required by the Life Pulse to produce the NOW settings on a patient. If the Servo Pressure changes, either suddenly or gradually, it may be that:

- Lung compliance is changing.
- A pneumothorax has occurred.
- Tension is developing on a pneumothorax.
- A right mainstem intubation has occurred.
- The patient needs suctioning.
- There is a leak in the tubing.

Not all alarms require emergency corrective actions. Use common sense. If the Life Pulse alarms are saying one thing, and clinical observation says another, react accordingly.

For example, if the humidifier displays a TEMP LOW alarm and the circuit and cartridge feels hot to the touch, place the humidifier into WAIT and replace the cartridge/circuit.

# KNOW THE LIFE PULSE

## 3. Know The Life Pulse

Third, **KNOW THE LIFE PULSE.**

Interpreting alarms is difficult, if not impossible, without a good working knowledge of the ventilator, how the feedback control mechanisms function, and what the various alarms mean.

- What conditions can cause an alarm?
- How does the Life Pulse respond to an alarm?
- What should the clinical response be?

Review this manual and study the Operator's Manual which, among other information, contains a comprehensive troubleshooting section.

Interpreting alarm conditions is made easier when you know, for example, the HIGH PIP alarm means that the Life Pulse has sensed PIPs 10 cm H<sub>2</sub>O greater than the set PIP for every breath during the last 30 seconds, or a sustained PIP 5 cm H<sub>2</sub>O greater for 1 second.

# COMMON THINGS HAPPEN COMMONLY

## 4. Common Things Happen Commonly

Fourth, common things are the most likely cause of the majority of alarms. **COMMON THINGS HAPPEN COMMONLY.**

- Perhaps ninety-five percent of alarms occur due to kinked, disconnected, or obstructed tubes. Knowing this information will help greatly in troubleshooting.

The solutions to these problems are equally as common:

- Unkink the tubes, reconnect the tubes, or clear the obstruction.

Again, if the Servo Pressure has locked at or near its last operating level, the tubing problem can be corrected without manual ventilation or changing conventional ventilator settings.

# USE AVAILABLE RESOURCES

## 5. Use Available Resources

### Examples of Available Resources

- In-service Manual
- Operator's Manual
- Service Manual
- Clinical Updates
- Newsletters
- Website - *www.bunl.com*
- **24 Hour Hotline**

Fifth, **USE AVAILABLE RESOURCES**. Bunnell Incorporated offers an Operator's Manual, newsletters, research articles, and a **24 hour Hotline**:

**1-800-800-4358**

When using the Hotline, make sure to gather as much information about the alarm condition as possible. The more facts you have about the situation, the better the assistance a clinical specialist can provide on the Hotline.

If an alarm condition cannot be corrected easily, perform a systems Test. The systems Test can help isolate the source of the alarm. If the Life Pulse passes the Test on the test lung, the cause of the alarm has to be in the ET tube or the patient.

Also run an operational test on a test lung to verify the Life Pulse's operation.

Remember to call as soon as possible after determining the alarm condition cannot be corrected.

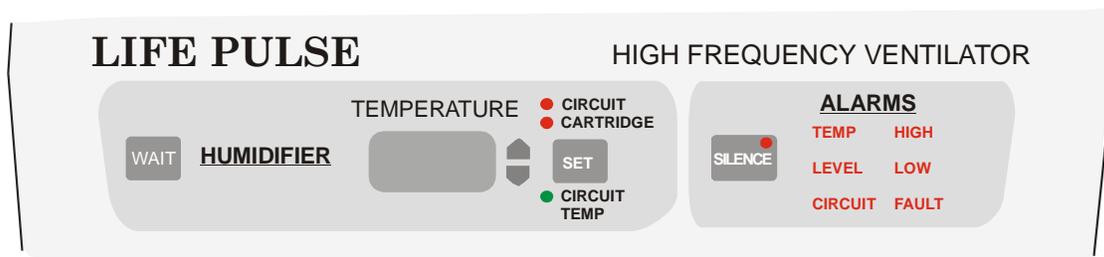
Do not hesitate to call if there are **any** question or concern. It is much better to call and have a **good** experience than not call and have a **bad** experience.

## Chapter 12

# HUMIDIFIER ALARMS

### Objectives

1. Recognize and correct the conditions that will produce humidifier cartridge/circuit alarms.
2. Understand the purpose and methods of controlling gas temperature in the cartridge and circuit.
3. Understand how cartridge temperature is linked with humidification and when and how to change this temperature.
4. Understand the importance of the **CIRCUIT TEMP**, **CARTRIDGE TEMP**, **WAIT** button, and **SILENCE** button.



The humidifier alarms are on the right side of the humidifier control panel.

Humidifier alarms will appear as red LEDs accompanied by an audible alarm. The alarm can be silenced for 60 seconds by pressing the **SILENCE** button.

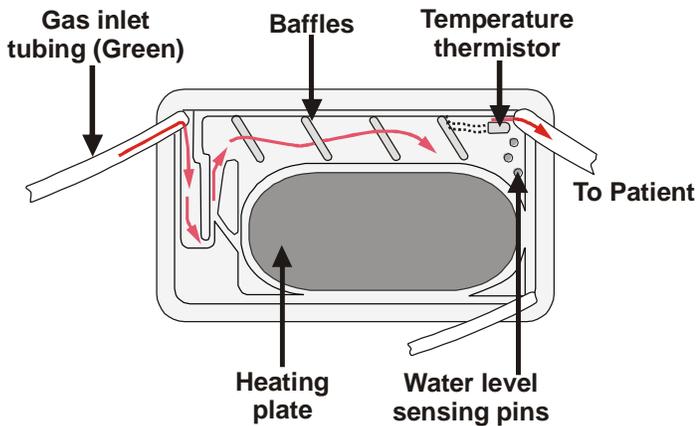
The humidifier alarm system detects high or low water levels and high and low temperature for both the circuit and cartridge.

The system also has an alarm for disrupted electrical connections between the humidifier and the cartridge.

# HUMIDIFIER OPERATION

Installation of a new humidifier cartridge/circuit includes observing the cartridge function for a few minutes.

After you press the **ENTER** button:



- The humidifier begins operating.
- The pump fills the cartridge with water.
- Water in the cartridge is heated by the hot plate behind the cartridge.
- The red circuit heater wire begins heating.
- The cartridge fills with water up to the point where the water contacts the first two level sensing pins.
- The pump stops pumping.

# CIRCUIT FAULT: LEVEL Alarm



The humidifier microprocessor knows that the pump should be able to fill the cartridge within eighty-six seconds. If the level sensing pins do not detect water within this period, the water pump will shut off and a **CIRCUIT FAULT: LEVEL** alarm will appear in the humidifier ALARMS window.

The alarm may be silenced for 60 seconds by pressing the humidifier alarm **SILENCE** button.

The **CIRCUIT FAULT: LEVEL** alarm indicates it is necessary to check the progress of the cartridge filling. If the water has reached the appropriate level as described above, the cartridge may need to be replaced.

If a **CIRCUIT FAULT: LEVEL** alarm sounds and the water has not reached it proper level, look for one of the following possible causes:

- The water supply and/or water transfer tubing may not be connected properly.
- The water transfer tubing may be clamped shut.
- The water supply may be empty.

If the **CIRCUIT FAULT** alarm sounds immediately after the **ENTER** button is pressed:

- The humidifier door may not be closed properly.
- The cartridge/circuit may be faulty.

If none of these conditions exists, call the **Bunnell Hotline** at **1-800-800-4358**.

# WATER LEVEL SENSING

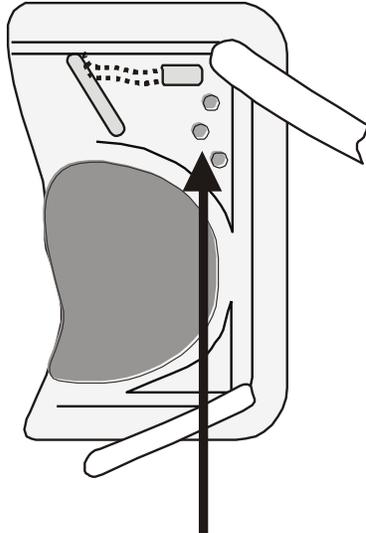
While observing the delivery of water to the cartridge, ensure that it does not overflow. The pump stops pumping when the water level reaches the second water level sensing pin.

The cartridge has a third level sensing pin to detect high water level and prevent overflow into the circuit. The water pump is stopped automatically if the water level reaches the third pin.

If the all level sensing pins are defective, the water level isn't sensed properly and a set fill time limit (86 seconds) is designed to turn off the pump in time to prevent overflow.

Whenever installing a new cartridge/circuit, observe the cartridge fill until the pump stops.

As the cartridge fills, the water and gas inside are heated by the hot plate behind the cartridge. The temperature is regulated by the white cartridge thermistor wire located near where the circuit tubing attaches to the cartridge.



**Water level sensing pins**



**Proper water level is at 2nd level sensing pin**

# CIRCUIT TEMPERATURE

The actual temperature of the gas is measured in the circuit just before the Patient Box and is displayed in the humidifier monitor section as **CIRCUIT TEMP** with a green light.



The actual Circuit Temperature will be 40° C and will be indicated by a green LED

As this temperature adjusts, it will approach 40° C, may overshoot slightly and then settle in right at or near 40° C.

There is approximately a 3° C drop in gas temperature from where it is last measured to where it enters the patient's trachea.

If the **set** circuit temperature is 40° C, the **actual** temperature of the gas as it enters the patient will be 37° C (body temperature).

The lungs are very effective heat exchangers. Unless there is a reason for wanting to raise or lower the patient's core temperature, **do not adjust the Circuit temperature to any value other than 40° C.**

# TEMPERATURE CONTROLS

We recommend that the set **CIRCUIT** temperature remain at its default setting of 40° C.



Pressing the SET button repeated will scroll through the Circuit, Cartridge, and Circuit Temp LEDs.

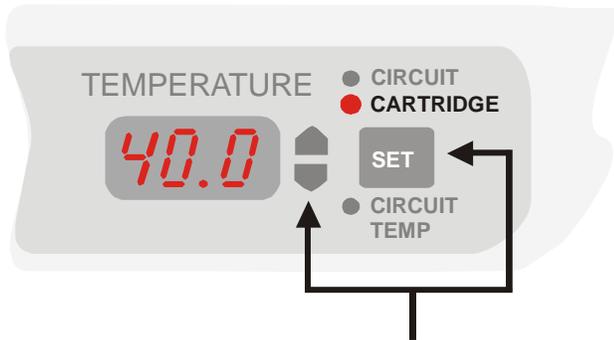
Adjust the Circuit Temperature only if the patient's temperature is not within an expected range, and if there is a reason to believe the temperature of the delivered gas may be contributing to the problem.

Adjusting the Circuit temperature may affect humidification in the circuit tubing. Be ready to change the Cartridge Temperature to provide appropriate levels of humidification.

The temperature in the cartridge and the circuit tubing are set and controlled independently. Pressing the SET button repeatedly causes the LED to alternate between CIRCUIT, CARTRIDGE, and CIRCUIT TEMP readings.

- A red or yellow light indicates a **set** temperature.
- A green light indicates an **actual** temperature.

# SETTING CARTRIDGE TEMPERATURE



Press the SET button twice then press the up or down arrows to change the Cartridge Temperature

The humidity levels of the gas delivered to the patient may be increased or decreased by raising or lowering the set **CARTRIDGE** temperature as follows:

- press the SET button twice to light the red or yellow LED next to CARTRIDGE, and
- adjust the temperature up or down by using the adjustment buttons.

The humidifier has no ENTER button. Wherever you leave the setting will be the temperature at which the heater will maintain the humidified gas in the cartridge.

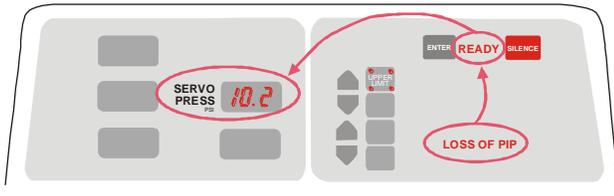
The humidifier will switch the temperature display back automatically to continuous CIRCUIT TEMP monitoring ten seconds after a button is pressed.

Remember that changes to the CARTRIDGE temperature affect humidification, not the temperature of the gas delivered to the patient.

# CONDENSATION PROBLEMS

## CARTRIDGE TEMP too high

A LOSS OF PIP alarm with the READY light on will lock the Servo Pressure.



The patient will continue to be ventilated appropriately.

If the preset **Cartridge Temperature is too high** for a particular patient:

- Excess condensation will develop in the clear portion of the Life Pulse circuit between the cartridge and the Patient Box.
- The MONITOR section of the Life Pulse will display fluctuating pressures.
- A LOSS OF PIP alarm may occur.
- As long as the Life Pulse is in the READY mode, the Servo Pressure will lock at or near its operating level, and the Life Pulse will continue to ventilate the patient appropriately during a LOSS OF PIP alarm

## CARTRIDGE TEMP too low

If the **Cartridge temperature is set too low**:

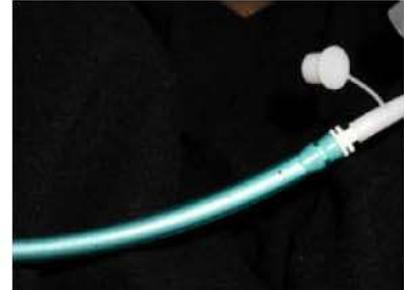
- The green portion of the Life Pulse circuit between the Patient Box and the LifePort adapter will be dry.



Over humidification

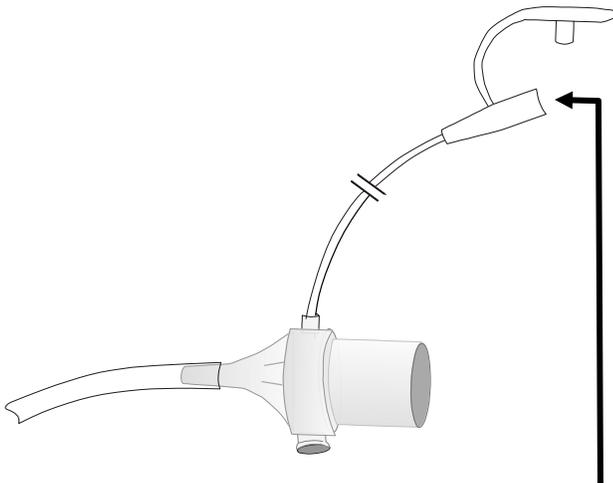


Under humidification



Good humidification

# MANUALLY PURGING PRESSURE TUBE



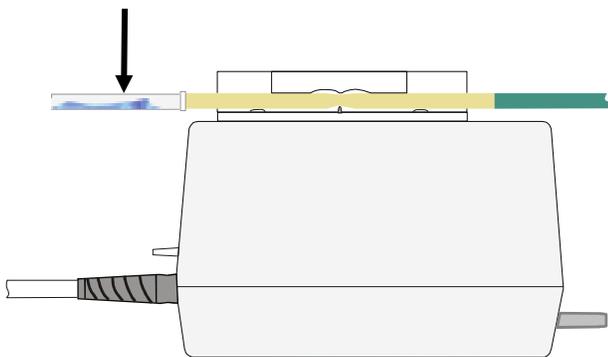
Purge pressure monitoring tubing with air from a syringe if condensation is partially obstructing the tube.

The pressure monitoring tubing is purged automatically every 15 seconds. If the Life Pulse monitoring senses that the pressure monitoring tube may be obstructed, the purge fires once per second until the obstruction is cleared.

However, if displayed pressures are erratic, the fluctuating pressures may be a result of excess condensation or mucus partially obstructing the pressure monitoring tubing. You may find that manually purging the pressure monitoring tubing, followed by suctioning of the ET tube may alleviate the problem.

- Manually purge the pressure monitoring tube of the LifePort adapter by flushing 2-3 cc of air from a needless syringe **before** manipulating the temperature settings.
- If the clear portion of the Life Pulse circuit collects water that migrates into the patient, lower the **CARTRIDGE** temperature.
- If condensation enters the endotracheal tube, it may be necessary to suction the patient. However, most of the water will be evacuated out of the ET tube into the conventional ventilator circuit because of the Life Pulse's expiratory flow pattern.

Lower Cartridge Temperature if water collects in the circuit.



# HIGH / LOW WATER LEVEL

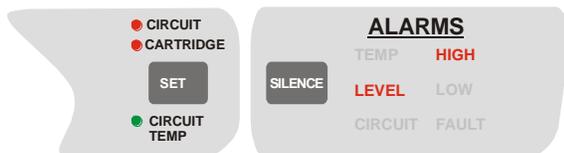


The humidifier alarm system detects high or low water levels for the cartridge.

A **LEVEL LOW** alarm may indicate that the humidifier water supply has been exhausted. The humidifier alarm **SILENCE** button can be pressed while a new water supply is connected as follows:

1. Close the clamp on the water transfer tube and disconnect the empty water supply bag.
2. Connect a new water supply.
3. Open the clamp on the transfer tube to allow water to flow to the cartridge.
4. Press the **WAIT** button twice (i.e., off, on) to give the pump time (86 seconds) to fill the humidifier cartridge.

Once the cartridge is filled and the pump has stopped, the pump is limited to 5 seconds of operation every minute. This restriction serves as a precaution against overfilling the cartridge during normal Life Pulse operation.



A **LEVEL HIGH** alarm rarely occurs but may be caused by a faulty humidifier cartridge. Replacing the cartridge/circuit usually eliminates this alarm.

A **LEVEL HIGH** alarm may occur when the water supply is hung above the Life Pulse, **and** the water supply tubing is not properly installed in the Life Pulse's water pump.

For this reason, the water supply bag should always be located below the level of the humidifier so that a **LEVEL LOW** alarm will occur when the water supply tubing is not properly installed.

# HIGH / LOW TEMPERATURE

The humidifier alarm system detects high and low temperature for both the circuit and cartridge.

A high or low temperature is indicated by an audible alarm and a **TEMP HIGH** or **TEMP LOW** message in the alarm display.

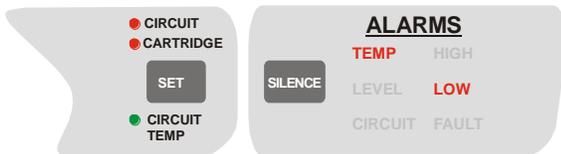
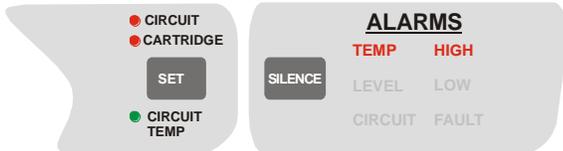
The **TEMP HIGH** alarm is activated if:

- the monitored temperature strays 3° above the set temperature for more than 1 minute in the **circuit**; or
- the monitored temperature strays 3° above the set temperature for more than 10 minutes in the **cartridge**.

The **TEMP LOW** alarm is activated if:

- the monitored temperature strays 3° below the set temperature for more than 3 minutes in the **circuit**; or
- the monitored temperature strays 3° below the set temperature for more than 30 minutes in the **cartridge**.

Such alarms may be caused by a faulty circuit relaying false information to the microprocessor. For example, if the circuit is quite warm to the touch when the humidifier is indicating that it is too cold, it could result in **overheating**. The humidifier circuit might need to be replaced in such conditions. **Call the Bunnell Hotline at 800-800-4358 before changing the circuit**



# POST-TEST QUESTIONS

## Section 1 OVERVIEW

1. The five subsystems of the Life Pulse are \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_.
2. Pressures measured in the patient are displayed in the \_\_\_\_\_ section.
3. To make ventilator changes in high-frequency Rate, PIP, and On-Time, use the buttons and displays in the \_\_\_\_\_ section.
4. The Patient Box is where blended gas is broken up into small “pulses” which then provide the patient with breaths necessary for ventilation.  
T  F
5. The Life Pulse is routinely used without attaching a conventional ventilator.  
T  F
6. The Life Pulse is designed to improve the patient’s blood gases while using less pressure.  
T  F
7. Each ventilator performs distinct functions when using a conventional ventilator in tandem with the Life Pulse. Check which ventilator primarily performs the following functions. Check both ventilators if they provide an equally important function.

**Life Pulse**

**Conventional**

___	a. Provides gas for patient’s spontaneous breathing.	___
___	b. Monitors Mean Airway Pressure (MAP).	___
___	c. Controls Positive End Expiratory Pressure (PEEP).	___
___	d. Controls high-frequency Rate and PIP.	___
___	e. Provides supplementary IMV.	___
___	f. Humidifies blended gas delivered to the patient.	___
___	g. Blends oxygen and compressed air.	___

8. A major advantage of the LifePort adapter is that reintubation is not required in order to provide high-frequency ventilation.  
T  F

# POST-TEST QUESTIONS

## Section 2 SET UP

### REAR PANEL

1. The Life Pulse's power cord may be plugged into a standard electrical outlet or an uninterruptible power supply.  
T  F
2. Oxygen and compressed air must be blended before entering the Life Pulse.  
T  F
3. At least 30 psi (206.85 kPa) of gas pressure must be supplied for the Life Pulse to operate.  
T  F
4. Analyzing FiO<sub>2</sub> is best performed by measuring directly from the air/oxygen blender.  
T  F
5. The Life Pulse alarm volume level is not adjustable.  
T  F

### FRONT PANEL

6. The disposable humidifier cartridge/circuit consists of which of the following:
  - a. Electrical sensors
  - b. Heating elements
  - c. Purge tubing
  - d. Humidification cartridge
  - e. All of the above
7. The pinch valve is located in the Patient Box.  
T  F
8. Either sterile water or normal saline may be used in the humidifier cartridge.  
T  F
9. Once the humidifier cartridge/circuit has been installed, three tubes will need to be connected to the front panel of the Life Pulse. Attach the small clear tube to the barbed connector labeled PURGE; attach the green gas inlet tube to the barbed connector labeled GAS OUT, and latch the clear water inlet tube into the pump housing.  
T  F
10. The pinch tube portion of the humidifier cartridge/circuit is the only tube that should be between the jaws of the pinch valve.  
T  F

# POST-TEST QUESTIONS

## Section 3

### VENTILATOR CONTROLS AND TEST PROCEDURE

1. An immediate audible alarm after the Life Pulse is turned on means the ventilator is defective.  
**T**     **F**
  
2. The STANDBY button stops jet ventilation from being delivered to the patient.  
**T**     **F**
  
3. The STANDBY button:
  - a. should be pressed each time a parameter is changed in the CONTROLS section.
  - b. puts the Life Pulse through a systems test.
  - c. creates a brief audible alarm every 30 seconds.
  - d. none of the above.
  
4. A systems TEST may be performed only with the Life Pulse in the Standby mode and should never be performed while the Life Pulse is attached to the patient.  
**T**     **F**
  
5. It is important to observe the front panel of the Life Pulse during the TEST procedure to assure all LEDs and displays are functional.  
**T**     **F**
  
6. Match each item in the first column with the single most accurate statement in the second column.
 

1. <b>ENTER</b> button	_____	a. Never pressed while the Life Pulse is attached to the patient
2. <b>NOW</b> settings	_____	b. Stops the audible alarm for 60 seconds
3. <b>TEST</b> button	_____	c. “Awakens” the Life Pulse into the Standby mode with an audible alarm
4. <b>ON</b> button	_____	d. Transfers NEW settings to NOW settings.
5. <b>NEW</b> settings	_____	e. Disconnected purge tubing
6. <b>SILENCE</b> button	_____	f. The current or active PIP, RATE, and ON-Time
7. <b>STANDBY</b> button	_____	g. Problem with connection at GAS OUT hose barb or with one of the Servo Pressure control valves
8. <b>VENTILATOR FAULT 02</b>	_____	h. Similar to Inspiratory Time
9. <b>VENTILATOR FAULT 03</b>	_____	i. Proposed PIP, RATE, and ON Time
10. <b>JET VALVE ON-TIME</b>	_____	j. Stops high-frequency ventilation delivery

# POST-TEST QUESTIONS

## Section 4

### PRESSURE MONITORING

1. What pressure is displayed in the MONITOR section when the Life Pulse is in the Standby mode and not attached to a patient?
  - a. Servo Pressure
  - b. MAP
  - c. proposed PIP
  - d. Zeros will be displayed
  - e. a., b., and c.
  
2. Once the pressure monitoring tube of the LifePort adapter has been connected to the Patient Box, the Life Pulse, in its Standby mode, will begin to monitor the pressures being delivered by the conventional ventilator. These pressures are measured every 2 milliseconds, averaged over \_\_\_\_\_ seconds, and updated on the display every \_\_\_\_\_ seconds.
  
3. Match one MONITOR feature in the first column with its definition in the second column:
 

1. <b>MAP</b> _____	a. The internal driving or working pressure required to ventilate the patient at the NOW settings
2. $\Delta P$ _____	b. Average of peak pressures measured in the LifePort.
3. <b>PEEP</b> _____	c. PIP minus PEEP
4. <b>PIP</b> _____	d. Average of pressures measured over the total area of the pressure waveform
5. <b>SERVO</b> _____	e. Average of minimum airway pressure
  
4. Bigger patients, or patients with more compliant lungs, require \_\_\_\_\_ (MORE/LESS) Servo Pressure.
  
5. The Purge system maintains the patency of which tube?
  - a. Jet port
  - b. Main port of the endotracheal tube
  - c. Pressure monitoring tube

# POST-TEST QUESTIONS

## Section 5 HUMIDIFIER

1. Lowering the cartridge temperature will reduce the amount of humidity in the gas but will not affect the temperature of the gas that is delivered to the patient.  
T  F
2. There are two separate temperature controls for the humidifier cartridge/circuit.  
T  F
3. Improper regulation of the humidity and temperature of the gas delivered to the patient may: (choose all that apply)
  - a. contribute to dehydration.
  - b. contribute to fluid overload.
  - c. raise the patient's body temperature.
  - d. lower the patient's body temperature.
  - e. contribute to mucus plugging.
4. It is important to check for proper humidification (misty or condensation) in the green portion of the Life Pulse circuit between the Patient Box and the LifePort.  
T  F
5. The humidity of the gas delivered to the patient is:
  - a. primarily controlled by the Circuit temperature.
  - b. determined by the Cartridge temperature.
  - c. controlled in response to measurements taken by the Cartridge thermistor.
6. The temperature regulation in the Patient Circuit tubing:
  - a. primarily controls the temperature of the gas going to the patient.
  - b. is used to control condensation in the Circuit tubing.
  - c. is controlled in response to measurements taken by the thermistor in the circuit just before the Patient Box.
  - d. a. and c. only.
7. The Circuit temperature stays at 40° C and the Cartridge temperature is adjusted as necessary to control condensation and rainout.  
T  F
8. If a small red light on the Humidifier's WAIT button is flashing, the Humidifier has been placed in its WAIT mode manually, and the button must be pressed by the operator to return the humidifier to normal operation.  
T  F

# POST-TEST QUESTIONS

## Section 6 START UP

1. To begin high-frequency Jet ventilation, attach the Life Pulse to the patient, monitor conventional ventilator pressures with the Life Pulse in Standby mode, and determine the initial Life Pulse settings.  
**T**     **F**
  
2. In the Standby mode, the pressures displayed in the MONITOR section are 80-second running averages updated every 10 seconds. During operation, the displayed pressures are 10-second running averages updated every 2 seconds.  
**T**     **F**
  
3. If air leak is the primary concern, select a PIP approximately 90-100% of the monitored conventional ventilator PIP. If the primary concern is RDS, select a PIP 100-110% of the monitored conventional ventilator PIP.  
**T**     **F**
  
4. Number the following Start-up steps according to the order in which they occur.
  - \_\_\_\_\_ a. Adjust PEEP, if necessary
  - \_\_\_\_\_ b. Select starting PIP
  - \_\_\_\_\_ c. Lower conventional ventilator Rate
  - \_\_\_\_\_ d. Lower conventional ventilator PIP if interrupting jet pulses
  - \_\_\_\_\_ e. Press ENTER button
  - \_\_\_\_\_ f. Press RESET button to establish new alarm limits, if necessary
  
5. A 10% drop in PIP with the Life Pulse typically results in a 20 to 25% drop in MAP, a reduction that may be too great in the RDS patient.  
**T**     **F**
  
6. After making a change in the conventional ventilator settings, it may be necessary to:
  - a. make the same changes on the Life Pulse.
  - b. press the RESET button to allow the Life Pulse to recalculate alarm limits around the Servo and Mean Airway Pressures.
  - c. lower the RATE on the Life Pulse.
  - d. Both a. and c.
  - e. None of the above.

# POST-TEST QUESTIONS

## Section 7 PATIENT MANAGEMENT

1. The thought processes and rationale for managing patients on the Life Pulse as compared with a conventional ventilator are very similar.  
**T**     **F**
  
2. Which of the following statements regarding patient management is (are) true? (Circle all that apply)
  - a. Most setting changes to manage  $PCO_2$  will be performed on the Life Pulse.
  - b. Most setting changes to manage  $PO_2$  will be performed on the conventional ventilator.
  - c. The Life Pulse is used in tandem with the conventional ventilator to provide better blood gases while using less airway pressure.
  - d. All of the above.
  - e. a. and b. only.
  
3. The best approach for dealing with a high  $PCO_2$  is to increase delta P ( $\Delta P$ ).  
**T**     **F**
  
4. Because  $CO_2$  elimination is proportional to Tidal Volume squared ( $V_T^2$ ) during high-frequency ventilation, small changes in which of the following parameters may produce significant changes in  $PCO_2$ ? (Circle all that apply)
  - a. PIP
  - b. PEEP
  - c. Delta P
  - d. All of the above
  
5.  $PCO_2$  would most likely \_\_\_\_\_ (INCREASE/DECREASE) if PEEP is increased to improve  $PO_2$ .
  
6. Increasing high-frequency PIP is a more effective means of eliminating  $PCO_2$  than increasing high-frequency Rate.  
**T**     **F**
  
7. The best approach for controlling  $PO_2$  is to adjust Mean Airway Pressure (MAP).  
**T**     **F**

# POST-TEST QUESTIONS

## Section 7 PATIENT MANAGEMENT Cont.

8. Which of the following strategies may be the most effective for increasing MAP and oxygenation?
- Increasing PEEP
  - Increasing conventional IMV
  - Increasing conventional inspiratory time
  - Increasing high-frequency On-time
  - Increasing high-frequency PIP

In the following two scenarios, match the most appropriate ventilator strategy with the patient's specific pathophysiology.

- |   |  |
|---|--|
| <p>9. A near term infant with a spontaneous pneumothorax and pneumomediastinum; minimal oxygenation concerns but excessively high PCO<sub>2</sub>.</p> <p>_____</p> | <ol style="list-style-type: none"> <li>Increase FiO<sub>2</sub></li> <li>Set initial conventional IMV rates 0 to 3 bpm</li> <li>Set initial conventional IMV rates 3 to 5 bpm</li> <li>Increase high-frequency PIP by 1 to 2 cm H<sub>2</sub>O</li> <li>Increase PEEP</li> </ol> |
| <p>10. A premature infant with RDS requiring high pressures; worsening oxygenation.</p> <p>_____</p>  | <ol style="list-style-type: none"> <li>Increase conventional IMV rate to 10 bpm</li> <li>Decrease PEEP</li> </ol>  |
11. Changing the high-frequency On-Time has not been proven an effective means of improving oxygenation.
- T**     **F**

# POST-TEST QUESTIONS

## Section 8 SUCTIONING THE PATIENT

1. There are three methods of suctioning a patient while on the Life Pulse.  
T  F
2. Secretions and suctioning frequency may \_\_\_\_\_ (INCREASE/DECREASE) during the first 4 to 6 hours of high-frequency ventilation.
3. The technique(s) for suctioning during high-frequency ventilation is (are):
  - a. to place the Life Pulse in Standby mode and suction normally.
  - b. to leave the Life Pulse running, instill normal saline down the Jet port of the LifePort adapter, and apply suction in both directions, while introducing and withdrawing the suction catheter.
  - c. to use a closed-suction system.
  - d. All of the above
4. If the Life Pulse is placed in Standby mode for suctioning, the patient will not require manual resuscitation or increased support from the conventional ventilator.  
T  F
5. With the Life Pulse running, if suction is not applied while introducing the suction catheter, the jet pulses will interrupt and a HIGH PIP alarm may occur, dumping the Servo Pressure safely to atmosphere.  
T  F
6. If the READY light is on while suctioning is performed with the Life Pulse running, the Servo Pressure is designed to lock at or near its baseline operating level and continue to ventilate the patient as requested.  
T  F

# POST-TEST QUESTIONS

## Section 9 WEANING

1. Which of the following statements regarding weaning is false?
  - a. If the Life Pulse is not needed for another patient, a baby may be weaned from high-frequency ventilation down to CPAP.
  - b. Weaning too quickly is a vital concern and should be avoided.
  - c. If a separate blender is being used to supply mixed gas to the Life Pulse, both blenders should be adjusted to wean  $\text{FiO}_2$ .
  - d. Conventional pressures and/or breaths may need to be increased gradually when the Life Pulse pressures have been decreased into the teens.
  - e. The Life Pulse Rate should always be lowered to its minimum setting of 240 bpm before returning the patient to conventional ventilation.
  
2. The Servo Pressure may indicate when a patient's compliance is improving.  
**T**     **F**
  
3. Generally, as  $\text{PCO}_2$  decreases, high-frequency PIP is lowered in increments of 1 to 2 bpm; as  $\text{PO}_2$  improves, the  $\text{FiO}_2$  or the parameters that produce MAP are lowered.  
**T**     **F**
  
4. When a patient begins to respond negatively to further decreases in pressure, it may indicate that the patient has reached a "pressure threshold" and further decreases are ill-advised until the patient has "acclimated" to the changes.  
**T**     **F**
  
5.  $\text{FiO}_2$  should be reduced to 40% or less before weaning PEEP.  
**T**     **F**
  
6. Interruptions in the jet pulses should never be allowed during any stage of the weaning procedure.  
**T**     **F**
  
7. The conventional ventilator rate and PIP usually need to be increased as Life Pulse PIP is weaned into the mid-teens.  
**T**     **F**
  
8. When the patient is stable and most of the chest rise is being provided by the conventional ventilator breaths, a trial of conventional ventilation alone may be attempted by pressing the STANDBY button on the Life Pulse.  
**T**     **F**

# POST-TEST QUESTIONS

## Section 10 VENTILATOR ALARMS

1. The four components of the ALARMS section are: upper and lower alarm limits, alarm messages, the SILENCE button, and the RESET button.  
**T**  **F**
2. The displayed values which have manually adjustable upper and lower alarm limits are: (check all that apply)
  - a. PIP
  - b.  $\Delta P$
  - c. PEEP
  - d. Servo Pressure
  - e. MAP
3. The READY condition is met when the monitored PIP has come to within \_\_\_\_\_ cm H<sub>2</sub>O of the set NOW PIP and has stabilized there for \_\_\_\_\_ seconds.
4. It is important to never walk away from the Life Pulse until the READY light is illuminated.  
**T**  **F**
5. The Servo and Mean Airway Pressure alarm limits are set automatically and are not manually adjustable.  
**T**  **F**
6. A JET VALVE FAULT alarm may indicate that the electronics controlling the pinch valve have failed.  
**T**  **F**
7. The patient should be left attached to the Life Pulse when pressing the TEST button to perform a systems test in the Standby mode.  
**T**  **F**
8. If the Life Pulse continues to run with the VENTILATOR FAULT message, chances are one of the ends of the purge tube has become disconnected.  
**T**  **F**
9. If a VENTILATOR FAULT 10 alarm occurs, the Life Pulse will resume operating when the ENTER button is pressed.  
**T**  **F**

# POST-TEST QUESTIONS

## Section 10 VENTILATOR ALARMS cont.

10. If the exhalation tubing of the conventional ventilator circuit becomes kinked, the Life Pulse: (choose two)
- initiates a HIGH PIP alarm.
  - initiates a LOW GAS PRESSURE alarm.
  - “dumps” the Servo Pressure to reduce the PIP.
  - locks the Servo Pressure at the current value.
11. Match the alarms in the first column with the descriptions in the second column:
- |                            |     |     |   |
|----------------------------|-----|-----|---|
| 1. <b>LOW GAS PRESSURE</b> | ___ | ___ | a. Unable to meet READY condition within 3 minutes of pressing ENTER button                       |
| 2. <b>CANNOT MEET PIP</b>  | ___ | ___ | b. Monitored PIP and PEEP come to within 2 cm H <sub>2</sub> O of each other                      |
| 3. <b>LOSS OF PIP</b>      | ___ | ___ | c. Gas supply drops below 30 psi (206.85 kPa)   |
| 4. <b>HIGH PIP</b>         | ___ | ___ | d. If occurs in Non-READY condition, Servo value drops to or near zero                            |
|                            | ___ | ___ | e. May occur on a patient who is too large to be ventilated by Life Pulse                         |
|                            | ___ | ___ | f. Leak in oxygen or compressed air hose  |
|                            | ___ | ___ | g. Monitored PIP exceeds NEW setting by at least 5 cm H <sub>2</sub> O continuously for 1 second. |
|                            | ___ | ___ | h. Servo Pressure is exhausted safely through “dump” valve to atmosphere.                         |

# POST-TEST QUESTIONS

## Section 11 INTERPRETING VENTILATOR ALARMS

1. Many alarms can be prevented by learning how the Life Pulse is designed, understanding its operation, and performing careful and thorough ventilator checks. However, when an alarm occurs, the first thing to do is look at the \_\_\_\_\_.
2. Some alarm conditions may require manual ventilation or increased conventional ventilator support while adjustments are made to the Life Pulse.  
**T**  **F**
3. “There is no substitute for a skilled and alert \_\_\_\_\_, \_\_\_\_\_, or \_\_\_\_\_.”
4. Careful observation is one aspect of using common sense when troubleshooting. An example of this skill is:
  - a. watching for appropriate chest rise.
  - b. looking for proper condensation in the circuit.
  - c. listening to the sounds of the Life Pulse for correct operation.
  - d. knowing baseline operating levels and observing trends.
  - e. All of the above.
5. If Servo Pressure exhibits an upward trend, the patient’s compliance may be improving or there may be an air leak, either in the patient or the cartridge/circuit.  
**T**  **F**
6. Knowing the ventilator is an important principle for understanding how to troubleshoot the Life Pulse.  
**T**  **F**
7. A majority of alarms are caused by kinked, disconnected, or obstructed tubes.  
**T**  **F**
8. One of the most important resources available to clinicians using the Life Pulse is the trained customer service representative answering the Bunnell 24-hour Hotline.  
**T**  **F**
9. The Operator’s Manual is a valuable resource for understanding the Life Pulse since it details information not covered in the In-Service Manual.  
**T**  **F**

# POST-TEST QUESTIONS

## Section 12 INTERPRETING HUMIDIFIER ALARMS

1. A humidifier CIRCUIT FAULT alarm may be caused by:
  - a. broken cartridge or circuit wires.
  - b. impaired contact between electrical connections (e.g., cartridge door open).
  - c. water in the cartridge not reaching the appropriate level within the allotted fill time.
  - d. All of the above.
  
2. The Circuit temperature is best left at 40° C because the gas temperature drops 3° from where it is last heated to where it enters the patient.  
**T**     **F**
  
3. Match the following:
 

Circuit temperature	_____	a. Primarily controls humidity of delivered gas.
Cartridge temperature	_____	b. Primarily controls temperature of delivered gas.
  
4. Which of the following alarms is not found in the Humidifier Section?
 

a. LEVEL LOW	b. TEMP HIGH	c. LEVEL HIGH
d. TEMP LOW	e. VENTILATOR FAULT	
  
5. Excessive rainout in the clear portion of the circuit may enter the ET tube and impede pressure monitoring causing a LOSS OF PIP alarm.  
**T**     **F**
  
6. If the cartridge door is closed and secured, if all tubing and electrical connections have been made, if water is in the water supply bag, and if the water transfer tubing is patent, and the humidifier appears to be working normally, a TEMP HIGH or LOW or a LEVEL HIGH or LOW alarm usually means the operator should:
  - a. press the WAIT button and continue delivering high-frequency Jet ventilation.
  - b. adjust the Cartridge and Circuit temperature settings.
  - c. probably replace the Humidifier Cartridge/Circuit.
  - d. call the Bunnell Hotline for additional troubleshooting ideas.
  - e. c and d only

# POST-TEST ANSWERS

## Section 1 OVERVIEW

1. **CONTROLS, MONITOR , ALARMS, HUMIDIFIER, AND the Patient Box.**
2. **MONITOR.**
3. **CONTROL.**
4. **True.**
5. **False.** The Life Pulse is always used in tandem with a conventional ventilator.
6. **True.** The conventional ventilator and the Life Pulse work synergistically to improve the patient's blood gases using less pressure, in most cases.
7.
  - a. **Conventional only.**
  - b. **Life Pulse and some Conventional.**
  - c. **Conventional only**
  - d. **Life Pulse only.**
  - e. **Conventional only.**
  - f. **Both.**
  - g. **Conventional.** (Unless the conventional ventilator has a low flow external output, a separate oxygen blender provides mixed gas to the Life Pulse)
8. **True.** The LifePort adapter replaces the standard ET tube adapter and obviates the need to reintubate the patient.

# POST-TEST ANSWERS

## Section 2 SET UP

1. **True.** However, the uninterruptible power source is more desirable.
2. **True.** The Life Pulse does not have an internal blender.
3. **True.** Pressures under 30 psi (206.85 kPa) will cause a LOW GAS PRESS alarm.
4. **True.**
5. **False.** The alarm volume knob is located on the rear panel of the Life Pulse.
6. **e.** All of the above.
7. **True.**
8. **False.** Only sterile water should be used to properly humidify the gas and assure normal function of the cartridge.
9. **True.** Once the cartridge is placed in the cartridge door and the door is closed, the tubes must be attached to the Life Pulse.
10. **True.** The pinch tube is the only circuit section flexible enough to function in the pinch valve.

# POST-TEST ANSWERS

## Section 3

### VENTILATOR CONTROLS AND TEST PROCEDURE

1. **False.** When the Life Pulse is powered up it always “awakens” in the Standby mode with the alarm sounding.
2. **True.** Pressing STANDBY is the accepted method of stopping high-frequency ventilation while still allowing the Life Pulse monitoring to be active.
3. **c.** In the Standby mode, the Life Pulse beeps six times every thirty seconds to inform you that it is not ventilating.
4. **True.** The TEST button should only be pushed with the ventilator attached to a test lung. Pressing the TEST button will not initiate the systems test when the Life Pulse is running.
5. **True.**
6. **1-d; 2-f; 3-a; 4-c; 5-i; 6-b; 7-j; 8-e; 9-g; 10-h.**

# POST-TEST ANSWERS

## Section 4

### PRESSURE MONITORING

1. **d.** “zero pressure.” All displays will be zero.
2. **“80”, “10”.** However, during operation all pressures are averaged over a 10 second period and the display is updated every 2 seconds. This approach helps to produce more stable readings.
3. **1-d; 2-c; 3-e; 4-b; and 5-a.**
4. **MORE.**
5. **C.** Pressure monitoring tube.

# POST-TEST ANSWERS

## Section 5 HUMIDIFIER

1. **True.** The cartridge temperature may be reduced to minimize condensation; however, the heated wire circuit will assure that the temperature of the gas remains stable.
2. **True.** Temperature in the cartridge and in the circuit tubing are controlled separately.
3. **a, b, c, d, e.** All of these are complications of improperly regulated humidification, with high-frequency ventilation and conventional ventilation.
4. **True.**
5. **b and c only.**
6. **d.** Condensation is controlled by adjusting the Cartridge temperature. The Circuit temperature should normally remain at 40° C
7. **True.**
8. **True.** If the humidifier is placed in the WAIT mode manually (indicated by a flashing WAIT button), it must be restarted manually.

# POST-TEST ANSWERS

## Section 6 START UP

1. **True.**
2. **True.**
3. **True.**            However, these starting criteria may vary depending on the patient's pathophysiology.
4. **a-5, b-1, c-4, d-3, e-2, f-6.**
5. **True.**
6. **b.**

# POST-TEST ANSWERS

## Section 7 PATIENT MANAGEMENT

1. **True.**
2. **d.**
3. **True.** Delta P can be increased by raising the Life Pulse PIP or by decreasing the PEEP.
4. **d.** Delta P is PIP minus PEEP.
5. **EITHER.** Raising PEEP might decrease Tidal Volume and may result in CO<sub>2</sub> retention if, despite raising PEEP, alveoli remain unstable at the end of expiration. However, if by raising PEEP the alveoli are stabilized at the end of expiration, CO<sub>2</sub> may decrease.
6. **True.**
7. **True.**
8. **a.** MAP and PEEP have a 1-to-1 ratio, meaning that raising the PEEP by 1cm H<sub>2</sub>O raises the MAP by 1 cm H<sub>2</sub>O.
9. **b, d, g.** Concern for pulmonary airleaks means limiting tidal volume from IMV breaths, but increasing minute ventilation using HFJV. Increasing HFJV PIP is more effective than increasing HFJV Rate for lowering PCO<sub>2</sub>. Decreasing PEEP will increase delta pressure, thus tidal volume, and may help lower PCO<sub>2</sub>.
10. **a, c, e, f.** Concern for oxygenation would lead to actions that recruit and maintain lung volume. Except for increasing FiO<sub>2</sub>, all options involve increasing Mean Airway Pressure. Using more IMV breaths improves lung volume recruitment, and raising PEEP maintains recruitment. Once oxygenation improves (alveoli are open and stable), wean the IMV rate as tolerated.
11. **True.** Clinical trials have shown that changing high-frequency On-Time has little clinical value, except possibly at slow ventilator rates while weaning and trying to maintain a desired I:E ratio.

# POST-TEST ANSWERS

## Section 8 SUCTIONING THE PATIENT

1. **True.**
2. **INCREASE.**
3. **d. (all of the above)**
4. **False.**
5. **True.**
6. **True.**

# POST-TEST ANSWERS

## Section 9 WEANING

1. e.
2. True.
3. True.
4. True.
5. True.
6. False.
7. True.
8. True.

# POST-TEST ANSWERS

## Section 10 VENTILATOR ALARMS

1. **True.**
2. **d. and e.**
3.  **$\pm 1.5$ , 20.**
4. **True.**
5. **False.** The Servo and Mean Airway Pressure alarm limits may be manually adjusted to suit the patient's needs.
6. **False.** The pinch valve will continue cycling but may be out of synch with the Life Pulse.
7. **False.** A test should only be performed with the Life Pulse connected to a test lung.
8. **True.**
9. **True**
10. **a. and c.**
11. **1-c and f; 2-a and e; 3-b and d; 4-g and h.**

# POST-TEST ANSWERS

## Section 11 INTERPRETING VENTILATOR ALARMS

1. **Patient (baby).**
2. **True.**
3. **Therapist, Nurse, Doctor.**
4. **e.**
5. **True.**           Increasing Servo Pressure may be an early warning indication of compliance improving, pneumothoraces, leaks in the cartridge/circuit.
6. **True.**
7. **True.**
8. **True.**           The Hotline number is 1-800-800-4358.
9. **True.**

# POST-TEST ANSWERS

## Section 12 INTERPRETING HUMIDIFIER ALARMS

1. **d.** All of the above.
2. **True.**
3. **Circuit-b; Cartridge-a.**
4. **e.** VENTILATOR FAULT
5. **True.** In this condition despite fluctuating PIP and PEEP displays, the Servo Pressure locks at or near its baseline operating level and the patient continues to be ventilated appropriately.
6. **e.** Any time there is a question about the Life Pulse or its alarms call the Hotline. Under the conditions described, the circuit may be faulty and need to be replaced.