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Application Notes

VT PLUS HF performance verification of Bunnell Life-Pulse HFJV (High Frequency Jet Ventilator)

VT PLUS HF provides a special mode for evaluating the performance of high frequency ventilators while connected to the patient y-piece of ventilator breathing circuit. A proper test load (calibrated test lung) should always be used to evaluate the performance of ventilators compared to their manufacturer's specifications and to ensure the ventilator will perform according to clinical expectations in real-use scenarios.

Brief HFJV intended use and theory of operation:

HFJV is a method of delivering oxygen-rich gases into the lungs to promote gas exchange across the lung-unit (alveoli)-to-blood tissue partition. The way that HFJV does this is by delivering the gas flow over short Inspiratory times (I-times), which provide two of the most important benefits of H F J V :

- small tidal v o l u m e s
- low alveolar pressures.

Small tidal volumes, when delivered with short I-times, make it impossible for the peak pressure used during HFJV to be transmitted to alveoli, thus protecting them.

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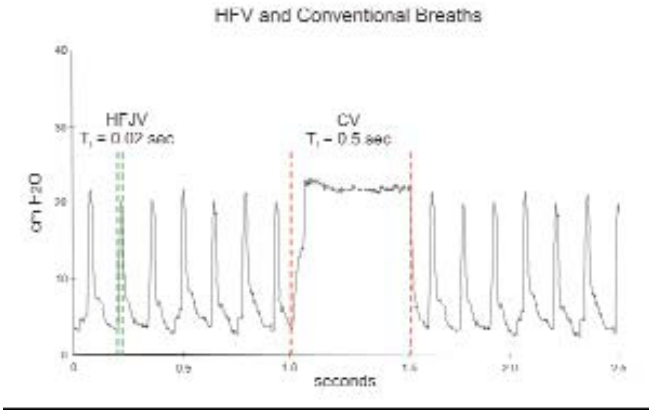
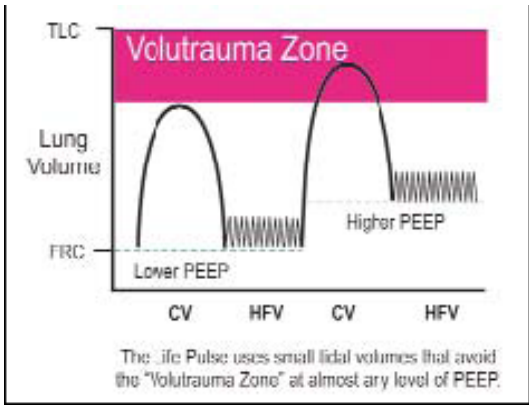
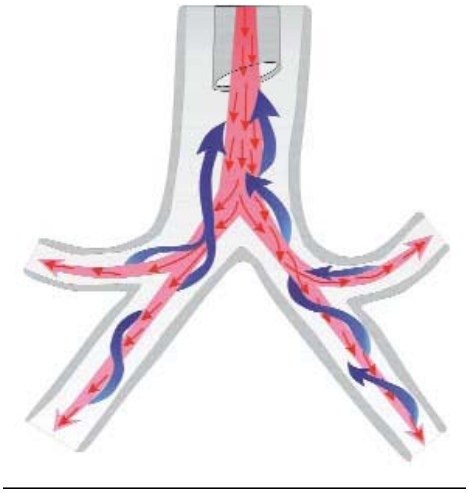




Squirting gas into the ET tube at high velocity allows gas to penetrate deeper into the lung with each breath, penetrating through dead space gas instead of pushing it ahead of the fresh gas. Delivering fresh gas in this way minimizes the size of each breath and pressure needed to deliver it to the aveoli. With fresh gas shooting down the center of the airways slower moving passive expiratory gas flow moves out along the airway walls. This countercurrent pattern facilitates airway clearance as shown in the following illustration.



PEEP controls mean airway pressure during HFJV, and MAP determines mean lung volume. Optimal PEEP/MAP facilitates oxygenation without the use of continual CV breaths. This strategy relegates CV breaths to intermittent use for alveolar recruitment.

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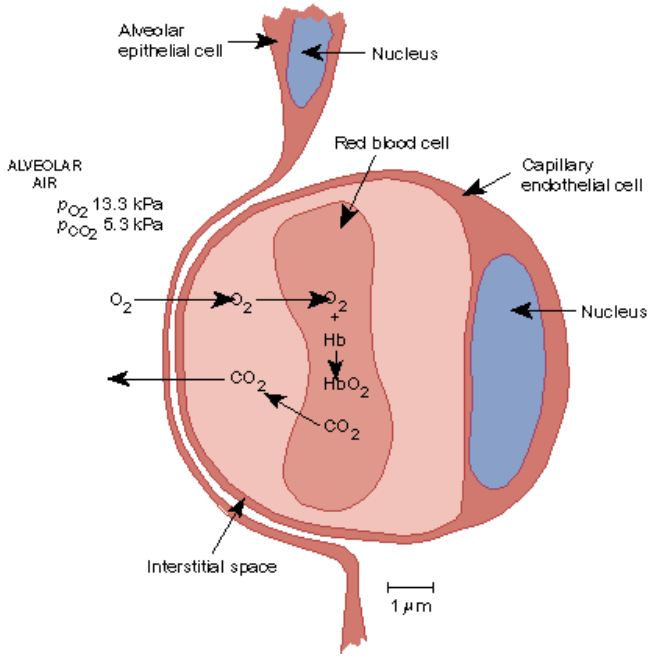
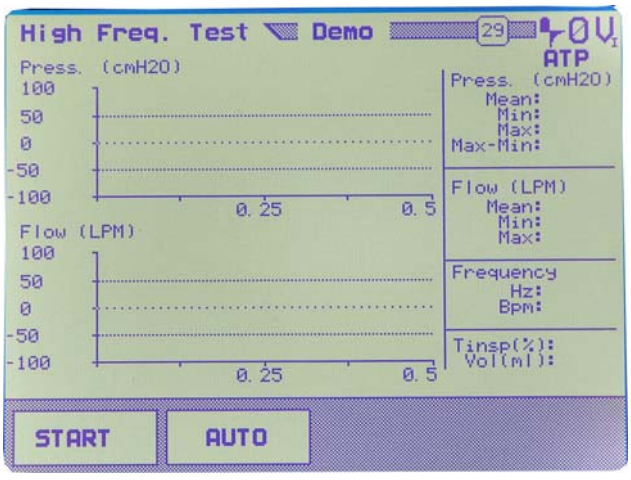


Contrast this with the way CMV (conventional mechanical ventilation) delivers oxygen-rich gases into the lungs to promote gas exchange. CMV introduces either a volume-limited, time-limited, or pressure-limited flow of gases into the lung so that the capacity of the lung is filled (lungs expand) and creates a pressure in the alveoli that exceeds the partial pressure of oxygen in the blood. Nature abhors such differences in pressure and will try to equalize them, so, the oxygen diffuses from the alveoli into the blood, and at the same time, because the partial pressure of carbon dioxide in the alveolar gases is low compared to the partial pressure of carbon dioxide in the blood, carbon dioxide diffuses from the blood into the alveoli and forms the majority of the gas mixture that is exhaled by the patient as the lungs contract.

How VT PLUS HF assesses the ventilation delivered during HFJV:



The High Frequency Mode of VT PLUS HF samples flow and airway pressure 5 times faster than during normal operation of VT PLUS HF. In High Frequency Mode, VT PLUS HF collects two seconds of data at a time. After the data is collected, it is processed to calculate the parameters. The first half second of data is plotted on the VT PLUS HF High Frequency Mode display. The Mean, Min (minimum), and Max (maximum)

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values are calculated for both pressure and flow signals using the entire 2 seconds worth of data. The breath rate is calculated and displayed in both Bpm (breaths per minute) and Hz (cycles per second). The inspiratory time and tidal volume are also calculated.

Note: tidal volume is most meaningful during CMV, since the objective is to fill the lung capacity to promote gas exchange. HFJV does not have the same objective, and therefore tidal volume is far less meaningful when using HFJV as a method of delivery of ventilation.

Assessing HFJV Performance versus the ventilator manufacturer's specifications:

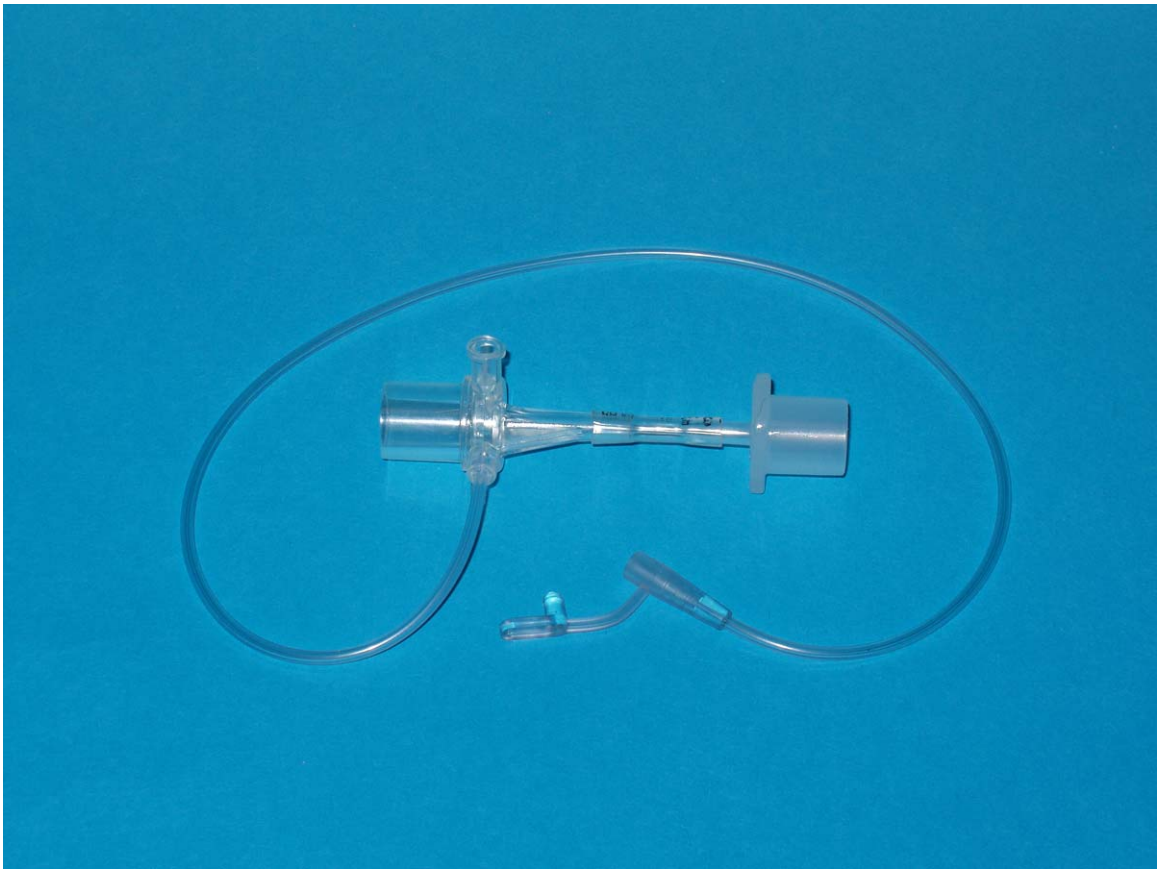
This inspection procedure assumes that the VT PLUS HF has been set-up properly with the Correction Mode: ATP; Gas Type: AIR; Gas Temperature, Ambient Temperature, and RH: per measured values of actual gas and ambient temperature, and RH. VT PLUS HF has an integrated barometer, however, actual barometric pressure should be verified using a laboratory-grade barometer without altitude compensation.

This inspection procedure was verified using a VT PLUS HF that had come to full stability (1 hour), and VT PLUS HF was zeroed prior to making measurements. The VT PLUS HF has a built-in 5 minute warm-up period, and an auto-zeroing function to remove offsets that may present themselves. VT PLUS HF also provides a manual zero control that can be used to eliminate any offset that may be present since the last auto-zero. We recommend that the manual zero control be used prior to recording measured values in this inspection, and that the measured values be allowed to settle before recording the measured values.

The following test equipment is required to perform this inspection:

1. VT PLUS HF
    a. HW ver. 1.01.01 or higher
    b. FW ver. 1.08.06 or higher

2. 3.5 mm LifePort ET tube adapter connected to a two inch long section of a 3.5 mm ET tube with a standard 3.5 ET tube adapter on the opposite end.



3. 3.5 mm ET tube adapter attached to a full length uncuffed 3.5 mm ET tube which was inserted into a black rubber stopper and a 500 ml Erlenmeyer flask (made by Naglene @ www.naglenunc.com).

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IMPORTANT: If the Life-Pulse HFJV fails to deliver the values prescribed in this application note (also found in the Bunnell labeling documents), contact Bunnell for repair/recalibration service.

1. Connect the Life-Pulse ventilator breathing circuit with 3.5 mm LifePort ET tube adapter connected to a two inch long section of a 3.5 mm ET tube with a standard 3.5 ET tube adapter on the opposite end to the High Flow Inlet of the VT PLUS HF

2. Connect the 3.5 mm ET tube adapter attached to a full length uncuffed 3.5 mm ET tube which was inserted into a black rubber stopper and a 500 ml Erlenmeyer flask to the High Flow Outlet of the VT PLUS HF

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3. Establish the following settings on the Life-Pulse ventilator:
    - PIP 20 cm H2O
    - PEEP 0 cm H2O
    - Rate 420 br/min
    - On time of 0.02 sec

4. Observe the following expected values on the VT PLUS HF HF-Mode display:
    - PEEP (minimum pressure): zero (0) ± 0.2 cm H2O
    - PIP: 19 cm H2O ± 0.5 cm H2O.
    - Rate: 420 br/min ± 1 br/min.

5. Establish the following settings on the Life-Pulse ventilator:
    - PIP: 40 cm H2O
    - PEEP: 0 cm H2O
    - Rate: 500 br/min
    - On time: 0.02 sec.

6. Observe the following expected values on the VT PLUS HF HF-Mode display:
    - PEEP (minimum pressure): zero (0) ± 0.2 cm H2O
    - PIP: 37 cm H2O ± 0.5 cm H2O
    - Rate: 500 br/min ± 2 br/min.

If you have questions about the set-up of the Life-Pulse Ventilator, please refer to the Life-Pulse operator's manual.

If you have questions about the set-up of VT PLUS HF, please first refer to the VT PLUS HF operator's manual (available for download from www.flukebiomedical.com), then call Fluke Biomedical Technical Support at:1-800-648-7952 option 2.

Fluke Biomedical wishes to thank Bunnell, Inc. for the use of the explanation of HFJV, and illustrations from their Technology and Clinical Report, Fall 2006, Vol. XI, No. 1. We further thank Bunnell, Inc. for their verification of the testing procedure described and review of this application note prior to publication. Any errors are those of Fluke Biomedical alone, and will be corrected on request.

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