**User Guide**

**How it works:**

The basis of this system is gravity, water and two PVC pipes to create an inherently pressure controlled system capable of ventilation. Each pipe is sealed at one end, the outside pipe is closed at the bottom, with a smaller diameter pipe inverted inside it and open at its base. Water in the system allows a seal to be made between the two pipes. By introducing air into the system, the top pipe is displaced upwards from its resting position. The water seal prevents it’s escape and we create a storage of pressure. The created pressure is a result of the weight of the system pushing the water column downwards, and subsequently, the water column’s equal upward force on the trapped air.

Air is supplied by a constant flow of gas coming from the hospital’s outlet. The hospital tubing is attached to a nipple on the top of the inner PVC pipe (a ¼” fitting required for hospital tubing).

Air/O2 builds up in the system and once the valve to the patient is opened, it is released through a port to the intubated patient. This valve is controlled on an electronic circuit, which gives the operator the ability to control respiratory rate, I:E ratio and amount of volume delivered to the patient. When the valve is closed, air volume builds in the system, and the inner pipe slowly rises. When the valve is open, the net flow of air is out of the system (air flow in<air flow out) and the inner pipe falls.

The pressure in the system is dictated by the total weight of the inside pipe, and can be modulated by adding weights to the top of the system to gain higher pressures. The total surface area of the water column being pushed down in this specific system is 478cm2. Therefore, adding 478g to the top of the system will displace 486ml of water 1 cm, and increase the total pressure by 1cm H2O.

The overall weight of the system does not change significantly with a drop in height of the inner pipe (ignoring buoyancy forces on the pipe that used to be out of the water and is now underwater). Now that we know pressure is a result of weight, we know that the pressure will not change significantly with a drop in height either. It is only the volume of the trapped air that changes significantly. Thus, this system can be thought of as an air flow capacitor, storing extra air molecules but without making them significantly more compressed as more are added.

**Link to youtube videos explaining our concept on a previous prototype:**

1. Concepts

<https://youtu.be/Rif06Y2mUV0>

1. Design + components

<https://youtu.be/FJwJgYTQQ7E>

1. Demonstration

<https://youtu.be/cVoM8isjuaQ>

1. Gravity Ventilator in action

<https://vimeo.com/402755875/e5e537c527>

**Setup:**

There is a small diameter (2”) PVC pipe running through the inside pipe and is open to the air, which allows for excess Air/O2 to escape the system in a controlled manner.

This system is designed to provide a breath to the patient with a constant and sustained pressure (stable plateau pressure). A manometer is connected to the inside pipe which provides constant feedback of the pressure within the system.

We have a sight glass set up that allows us to visualize the volumes delivered to the patient (though this is not necessary in a final model). This also allows us to visualize how much water is in the system.

As there is interaction between the air delivered to the patient and the water within the system, we have the water in the system sterilized by a UV light pump system at 23mcgW/cm2. This filtration system is attached to the bottom of the outer PVC pipe.

Though not installed in this system, we will place a spout at the base of the system, to allow for easy drainage of the water from the system.

To set up the system, connect all tubing as detailed in the assembly guide. The UV light/pump and the circuit board need to be plugged into a standard wall plug. Add ~8L of water to the outer pipe (filled until approximately 5cm high on the sight glass). To start the system, set the respiratory rate and I:E ratio on the circuit and turn the wall O2/air blender onto 8-10L/min. The system should start running and deliver breaths to the patient at the rate you set on the circuit. To change the pressure, add or remove weight from the top of the ventilator (there is a tube coming out of the top of the ventilator that holds the weight). Adding 478g increases the pressure by 1cm H20.

**Operation**:

There are two modes of operation that can be used with this ventilator:

Volume Control Mode: provides consistent tidal volumes at regular intervals for patient breathing, given adjustable breaths per minute and inspiratory/expiratory time ratio.

Pressure Control Mode: allows the patient to trigger a new mechanical breath during expiration, given a variable mandatory breath rate and trigger pressure threshold.

To turn on the ventilator:

1. Connect the ventilator to the power source. Display should show ‘Ventilator OFF’.
2. Use the slide switch to select desired operation mode:
   1. Volume Control Mode
   2. Pressure Control Mode
3. Turn the knobs to adjust for the desired parameters of the selected operation mode as shown in the table below:

|  |  |  |
| --- | --- | --- |
| **Knob** | **Timing Mode** | **Pressure Control Mode** |
| 1 | Inspiration/Expiration Ratio  (Range: 1:1 – 1:5) | Max Time Before Inhale  (Range: 750 – 6000ms) |
| 2 | Breaths per Minute (BPM)  (Range: 5 – 40) | Inhalation Trigger Pressure Threshold  (Range: -4 – -1 cmH2O) |
| 3 | N/A | Max Time Before Exhale  (Range: 750 – 6000ms) |

\*Note: parameters can only be adjusted while the ventilator is off.

1. Press the button labelled Start/Stop to turn on the ventilator. Display should show ‘Ventilator ON’.

To turn off the ventilator:

**WARNING:** follow the following steps to safely disconnect a patient from the ventilator. Doing so will allow the air in the system to pass through a filter before being expelled.

1. Step 1 - Turn off Ventilator
2. Step 2 - Turn off Source Flow
3. Step 3 - Disconnect Patient by disconnecting the HME from Ventilator Circuit, keeping HME attached to ETT - Direct circuit into gauze while pressure and flow from gravity chamber is released.
4. Step 4 - Begin Manual ventilation to support patient.