Operation

Updated 28 March 2020

This page describes the operation of the MIT E-Vent Units 002. (Three units of the same design exist.) This is our best attempt to provide a minimally viable control system with wide applicability globally. Groups may want to add additional layers of safeties. This is just a guide.

Note: While the mechanical hardware design is changing rapidly and some of the underlying electronics are being upgraded for prototype purposes. the operating principles are relatively design frozen.

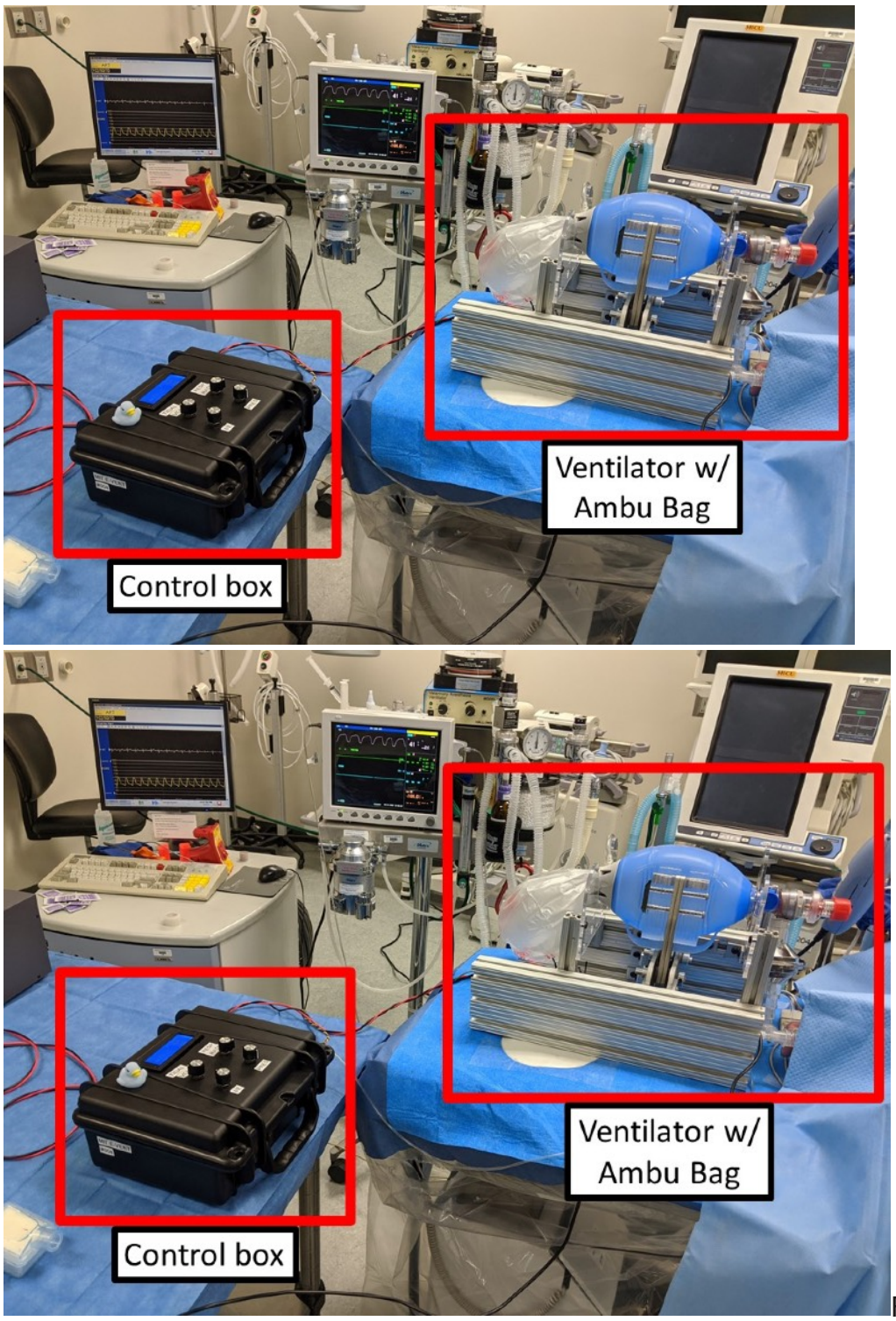


Figure 1. The two main components: the control box and the ventilator at a testing facility.

Scenario

The system will initially be setup by a clinician explicitly skilled in respiratory management. The parameters must be tuned and the patient monitored carefully. Once stable, they can be left in the care of a clinician not skilled in respiratory management. In the case of any change in patient condition or an alarm, the system must again be tuned by a skilled

clinician. In the case of any serious concern, the bag can be manually removed from the machine and squeezed by hand until the fault is addressed.

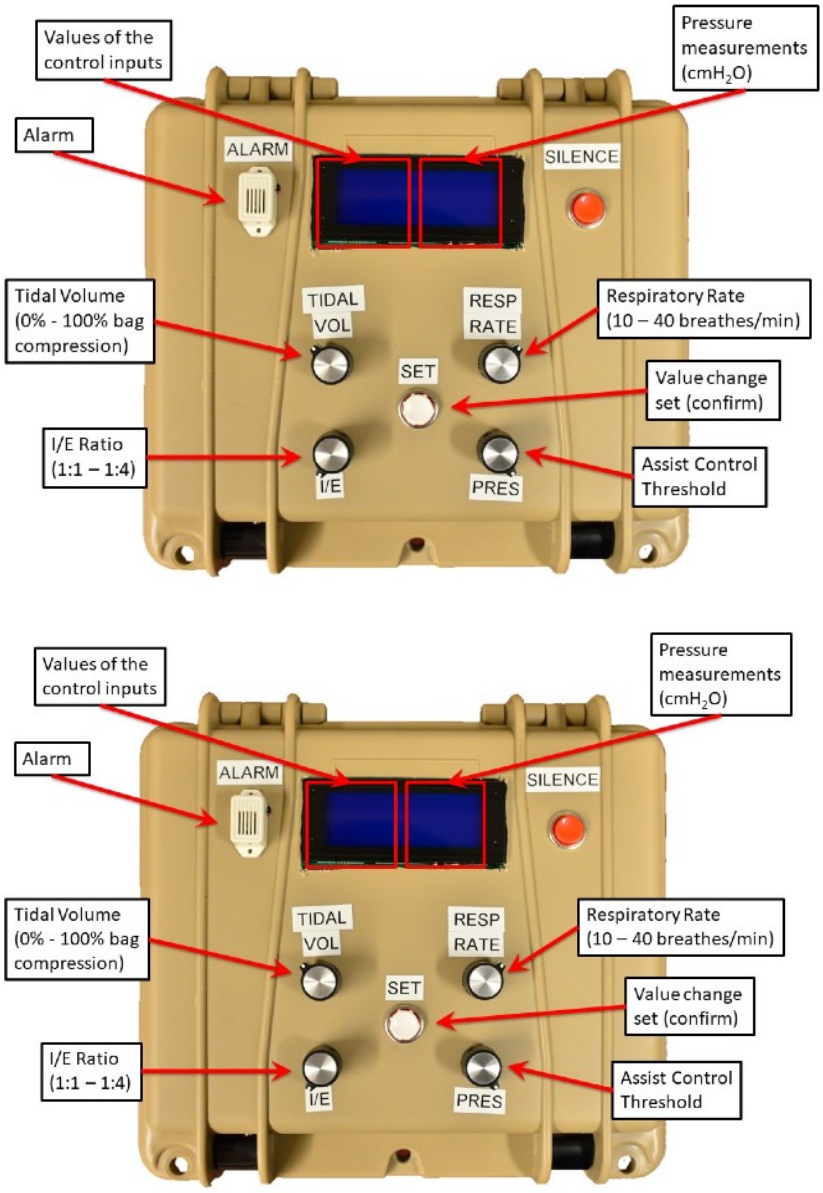
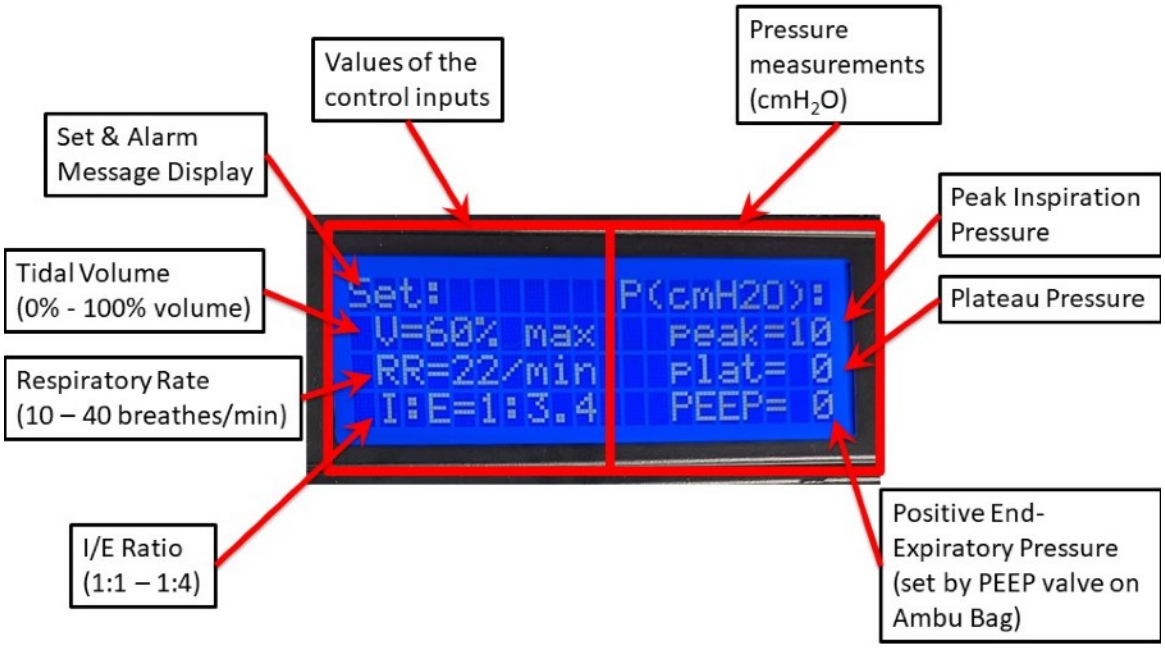


Figure 2. Control the ventilator and read pressure information from the top of the control box.



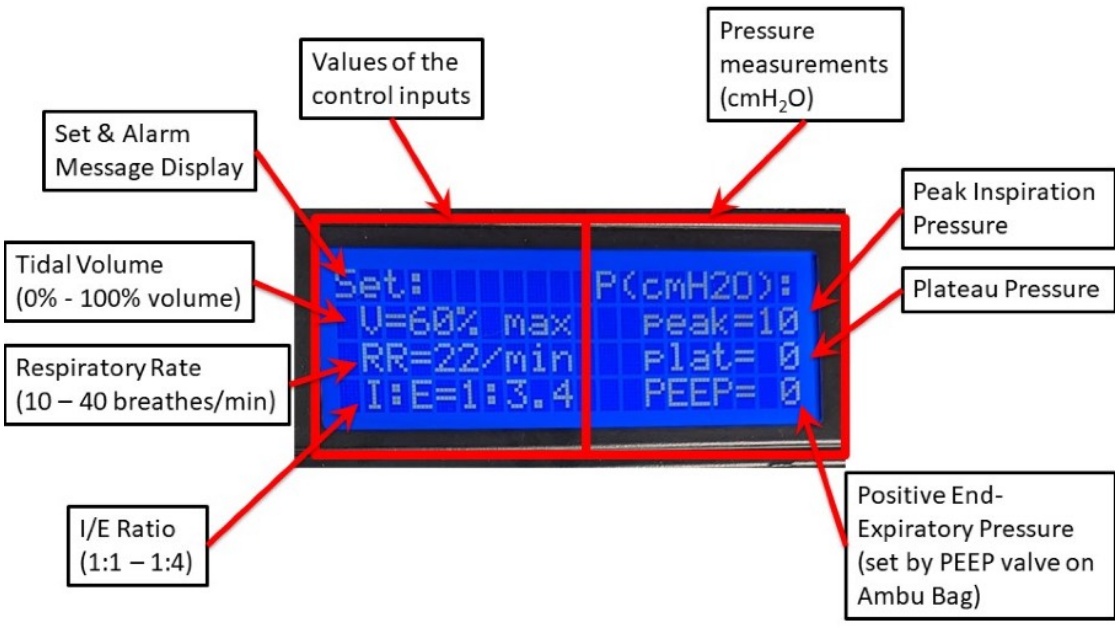


Figure 3.

There are 6 pieces of information displayed on the LCD screen which update after each breath cycle. Alarm messages will display on the top bar.

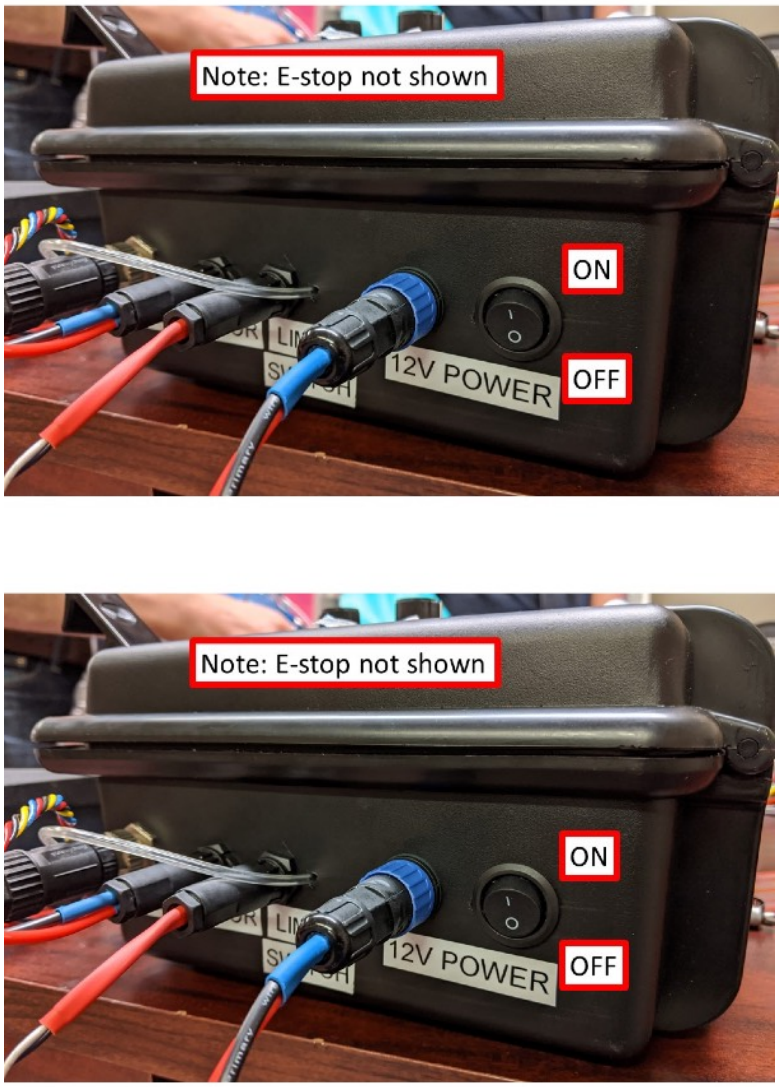


Figure 4. Ensure that all wires are connected and that the power switch is in the off position.

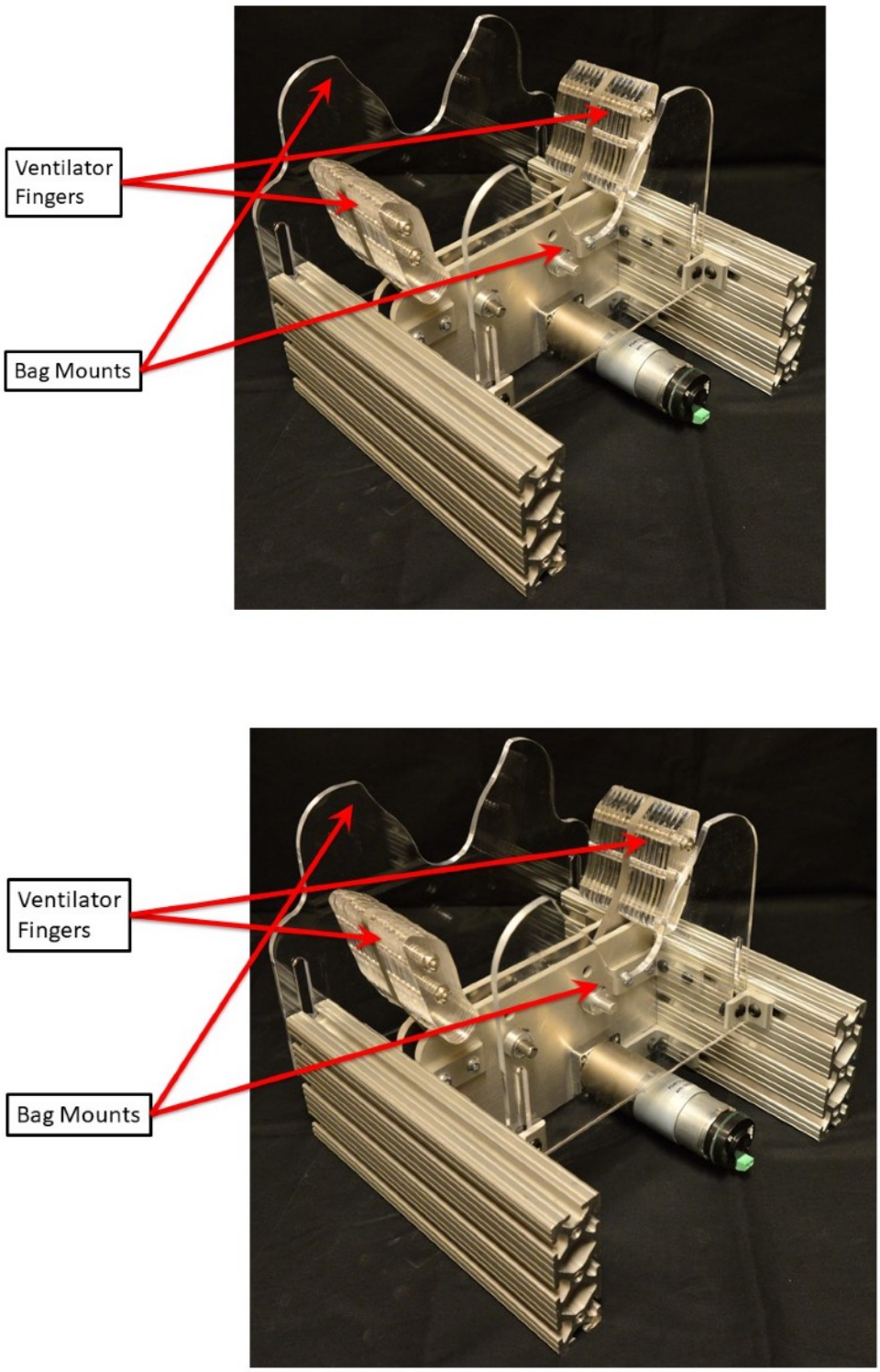


Figure 5. The ventilator fingers in ward motion controls the inflation and deflation of the bag. The clear sheets on either side of the fingers are for mounting the bag. These are replaced with adjustable metal mounts.

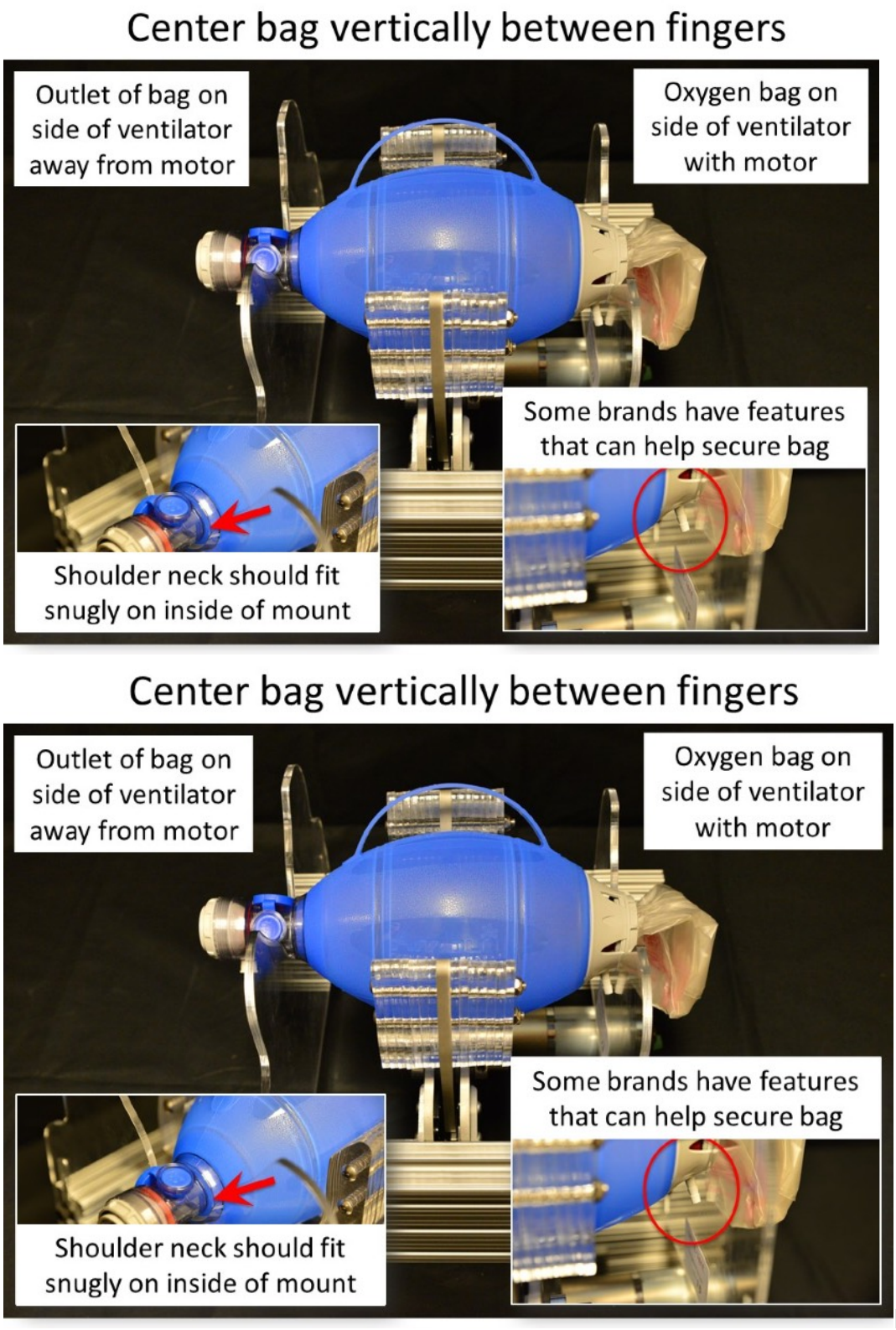


Figure 6. Correct bag placement is centered between the fingers vertically and axially. Confirm placement by manually moving driving the fingers to lightly touch the bag. Supports should be adjusted vertically and laterally to support the bag in this operating position.

Operation

1. Gently open the fingers by hand if not already open. This takes some force, but it is safe.
2. Position the Ambu Bag in the cradle between the fingers, following the directions given in Figure 6.
3. Ensure that all dials shown in Figure 2 are turned counter clockwise to the lowest position.
4. Check that nothing is in the way of the fingers.
5. Power up the system. The system will start moving immediately and home to the fully open position. Then it will slowly move to the edge of the bag. (This position is hard coded; it could be settable in a more sophisticated version.)
6. Set the desired *Respiratory Rate*, *Tidal Volume* and *I:E* knobs, as shown in Figure 2, and confirm the values on the display, shown in Figure 3. Press the *Set* button to apply.
7. Increase the *Tidal Volume* to a low setting (as determined by clinician) and press the *Set* button to apply. The system will start pumping. Confirm correct operation.
8. Once the machine is confirmed pumping, connect to patient and increase the *Tidal Volume* to the desired larger value and press the *Set* button.
9. Monitor the peak and plateau pressures and adjust parameters as per clinical guidance. PEEP pressure should be observed to match the setting on the PEEP valve.
10. Do not leave the patient unattended.
11. Monitor vital signs, listen for alarms and respond.
12. If Assist Control mode is desired, increase the *Threshold* knob and press the *Set* button to apply. This will increase the setpoint with respect to the PEEP.
13. *Respiratory Rate* should beset to less than the expected patient respiratory rate, i.e. the machine waits longer than the patient would.

Note: Spinning potentiometers (POTs) will cause the display valued to change, but will not change machine behavior until the *Set* button is pressed. If the *Set* button is not pressed within 5 seconds to apply the new settings system will alarm.

Caution: If a POT is changed, but Set is not pressed, a potentially confusing situation will arise whereby the machine is different from knob settings. Potential solutions better than the alarm include: 1. Shielding the potentiometers to prevent accidental turning. 2. Using a

potentiometer that must be pulled out to set. 3. A rotary encoder with a pushbutton; this will allow the button to be activated, set and deactivated. More sophisticated hardware and software solutions can be implemented.

Alarms

In the case of an alarm, the system should attempt to maintain operation. The Silence button will pause the alarm for 1 minute. Alarm conditions are checked for once per cycle.

Caution: Not all of these alarms are fully implemented. The logic is still being developed. This is not an exhaustive lists of failure conditions.

Alert	Condition detected	Response
ASSIST A	Whenever the patient fails to trigger inhalation the alarm sounds for 1 s	Clinician adjusts respiratory parameters as per clinical guidance
NOT SET	Potentiometer has been moved but change was not confirmed	Machine maintains settings Pressing *Set* button sets values and clears alarm
LOW PRESSURE	Pressure lower than expected (how to define this is an open question)	Machine maintains operation Clinician corrects situation; alarm will clear
HIGH PRESSURE	Pressure reached 40 cm H2O (pop off will activate)	Machine maintains operation Clinician corrects situation; alarm will clear
POSITION ERROR	Arms do not follow commanded position and velocity; probable mechanical interference of encoder fault	Home for ~3 seconds: re-initiate operation If condition corrected alarm clears If not corrected, convert to manual bagging

ELECTRICAL	Motor drew excessive current or controller overheats; probable mechanical interference or electrical fault	Clinician corrects situation; alarm will clear If not corrected, convert to manual bagging
HOMING FAULT	The homing switch was not touched during homing or touched during operation	Clinician corrects situation; restart