Patient Diaphragmatic Effort Lung Simulator, Team Breath, BME 200/300

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Function:

Mechanical ventilation (MV) is often needed in hospitals. Unfortunately, when a patient is intubated they are likely to develop ventilator-induced diaphragm dysfunction (VIDD), a condition characterized by diaphragm atrophy and dysfunction. Stimdia Medical has developed a system that aims to alleviate this effect via paced stimulation of the phrenic nerve (pdSTIM system). Currently, lung simulators cannot model any patient effort during MV, which is problematic because some patients can produce limited diaphragmatic effort, and also because the pdSTIM systems induces patient effort. Consequently, the team is tasked with modifying a commercially available lung simulator so that patient effort may be incorporated and used to influence future designs of the pdSTIM system.

This modification to the lung simulator, the Michigan Instruments Test Lung, must generate a pressure of -50 cmH_2O. The way in which this is accomplished is still to be determined, but the final design will need to be controlled via a Simulink interface that allows the user to input breath rate, Ti, waveform selection, lung compliance, and the minimum P_{mus} force.

Client Requirements:

- Design a system that modifies a Michigan Instruments Test Lung to incorporate patient effort so that work of breathing may be simulated
- Choose and justify a motor and motor controller that would be able to simulate patient effort (if this option is chosen). The motor should generate a maximum force, P_{mus} of -50 cmH_2O.
- Choose and justify a DC power supply to power the motor (if this option is chosen)
- Build a mount to hold the motor and motor controller
- The modification must be controlled via a Simulink driver, where the user can input breath rate, Ti, waveform selection, lung compliance, and the minimum P_{mus} force.
- Develop a general theory of operation document.

Design Requirements:

Physical and Operational Characteristics:

1. Performance Requirements:
    a. Must be able to provide a pressure of -50 cmH20
    b. Must be able to vary the force to simulate the different magnitudes of patient effort
    c. Must be compatible with the Michigan Instruments Lung
    d. Must be able to input breath rate, the desired P_{mus} waveform, lung compliance, and a minimum P_{mus}
2. Safety:
    a. Must be able to safely simulate patient effort without damaging the Michigan Instruments Lung
    b. Must be able to safely operate while a ventilator is attached to the Michigan Instrument Lung
    c. The device will use a DC power source, so care must be taken to prevent electrocution and fire hazards. There can be no exposed wires.

3. Accuracy and Reliability:
    a. Must be able to simulate a maximum P_{mus} of -50 cmH_2O
    b. The motor must be able to deliver sufficient torque to provide a force range of 15 to 60 N.
    c. It is desired that the motor produce a repeatable P_{mus} every time, within +/- 1 cmH_2O
    d. It is desired that the motor produce a P_{mus} within +/- 1 cmH_2O of the value the Michigan Instruments Test lung reads

4. Life in Service:
    a. The simulator must be able to be shipped cross-country and be easily assembled.
    b. The device must function for as long as Stimdia Medical needs it to test their products. An estimate of this time period is three years of being used five days a week for one hours a day.

5. Shelf Life:
    a. Although there are no plans to keep the device in storage, this could change. Since the device will have a motor, current controller, and batteries, it should be kept in a dry place at room temperature to give it the longest shelf life.

6. Operating Environment:
    a. The device will be used at room temperature, normal pressure, normal humidity, and free from any extreme conditions (shock loading, dirt or dust, insects, etc.).

Using the device in any of these conditions could compromise its function. It should only be operated by someone trained to do so.

7. Size:
    a. The device, when taken apart, should be small enough to fit in a box that can be sent in the mail.
    b. The device should be relatively easy to set up and take apart for transport purposes.

8. Weight:
    a. The weight of the device should not exceed what an average person can carry.

9. Materials:
    a. All materials used will not be toxic.

10. Aesthetics, Appearance, and Finish:
    a. The device should be relatively easy to set up and take apart for transport purposes. The end product should be cleaned up (ex: no sharp edges, extra rope, etc.)

<u>Product Characteristics:</u>

1. Quantity:
    a. One patient effort simulator must be produced.

2. Target Product Cost:
    a. The target cost of the simulator is under $1000. As there should be few manufacturing costs, the team will try to keep costs low as possible by purchasing parts with a good balance between cost and effectiveness.

<u>Miscellaneous:</u>

1. Customer:
    a. The customer, Stimdia Medical, is a company that creates biomedical devices. This solution, if effective, will help them modify their phrenic nerve stimulator.
2. Competition:
    a. While there are test lungs out there, there are no existing patient lung effort simulators. The competing method of producing patient effort is to manually raise the test lung bellows to simulate a given pressure. This method will be useful for calibration.