



Animal Ventilator for Hyperpolarized Gas MRI



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Abstract

The use of hyperpolarized Helium (³He) as a contrast agent in Magnetic Resonance Imaging (MRI) is an emerging technique for diagnosing diseases or abnormalities in the respiratory tract. Current methodology allows for MRI scans to be taken during inhalation of helium every fourth breath to allow adequate oxygen for the subject. A device and/or method is needed to function as an oxygen ventilator and serve as a means to integrate hyperpolarized helium into the respiratory tract of small animals on every breath.

Problem Definition

Create or redesign a small-animal ventilator capable of delivering constant volumes of ³He and Oxygen gas (1-20 mL) at user-specified frequencies (1-100 cycles/min) for safe and compatible use in MRI.

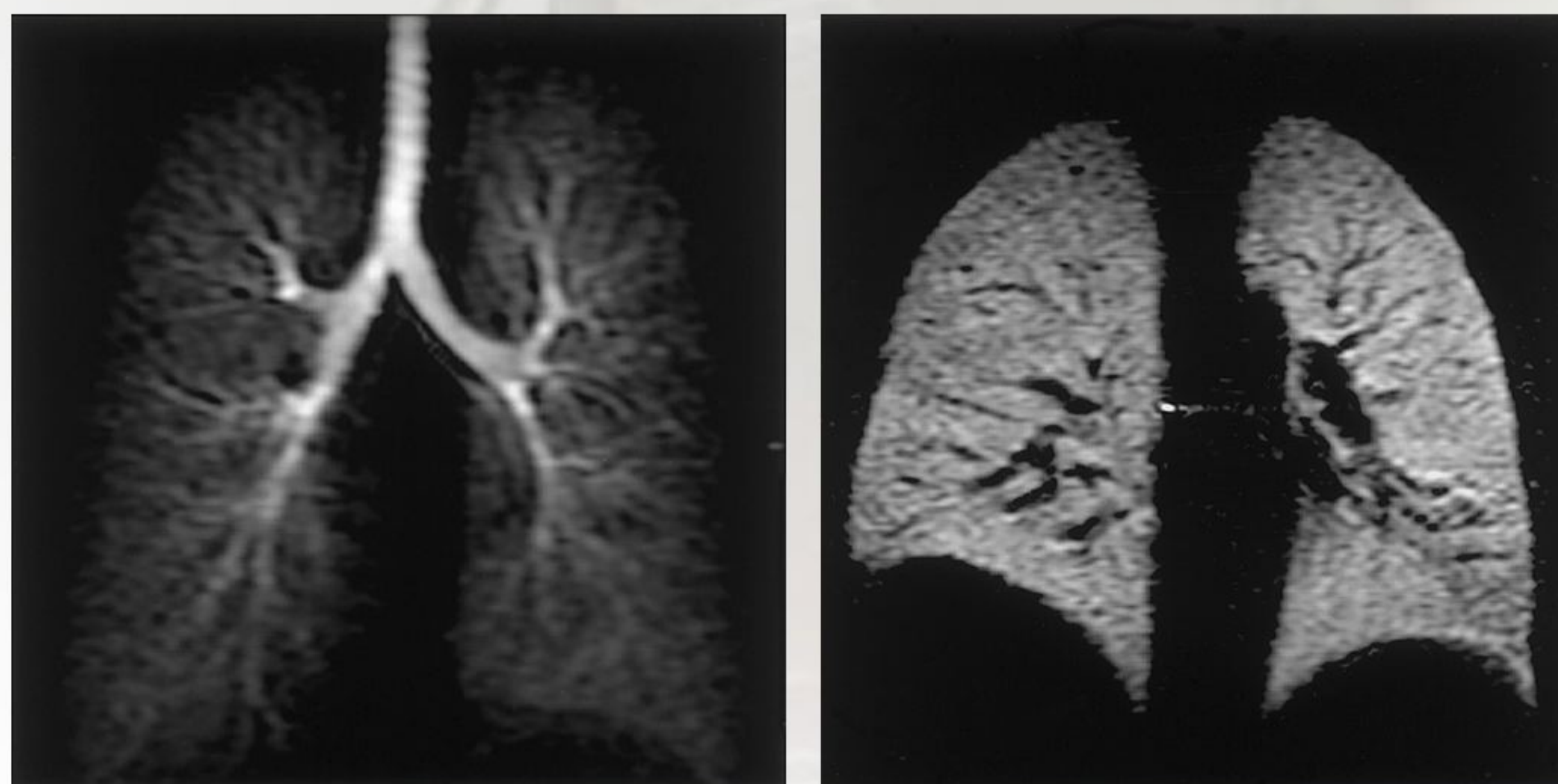
Objectives for this semester include increasing accuracy and precision of the device with a second-generation prototype. Additionally, the current timing of the valves cause an undesirable “oxygen chaser” after each helium breath, and a solution to this problem is also desired.

Client Study

If ³He MRI can accurately detect airways and air spaces, one could postulate that respiratory diseases such as asthma could be diagnosed with the use of this process. Ideally, ³He MRI will successfully reveal information that will lead to diagnoses of respiratory diseases. Physicians will be better able to assess the patient’s condition by viewing accurate images of their airway channels and lungs. The study uses ³He MRI to assess the capability of successful diagnosis of a respiratory disease-induced small animal.

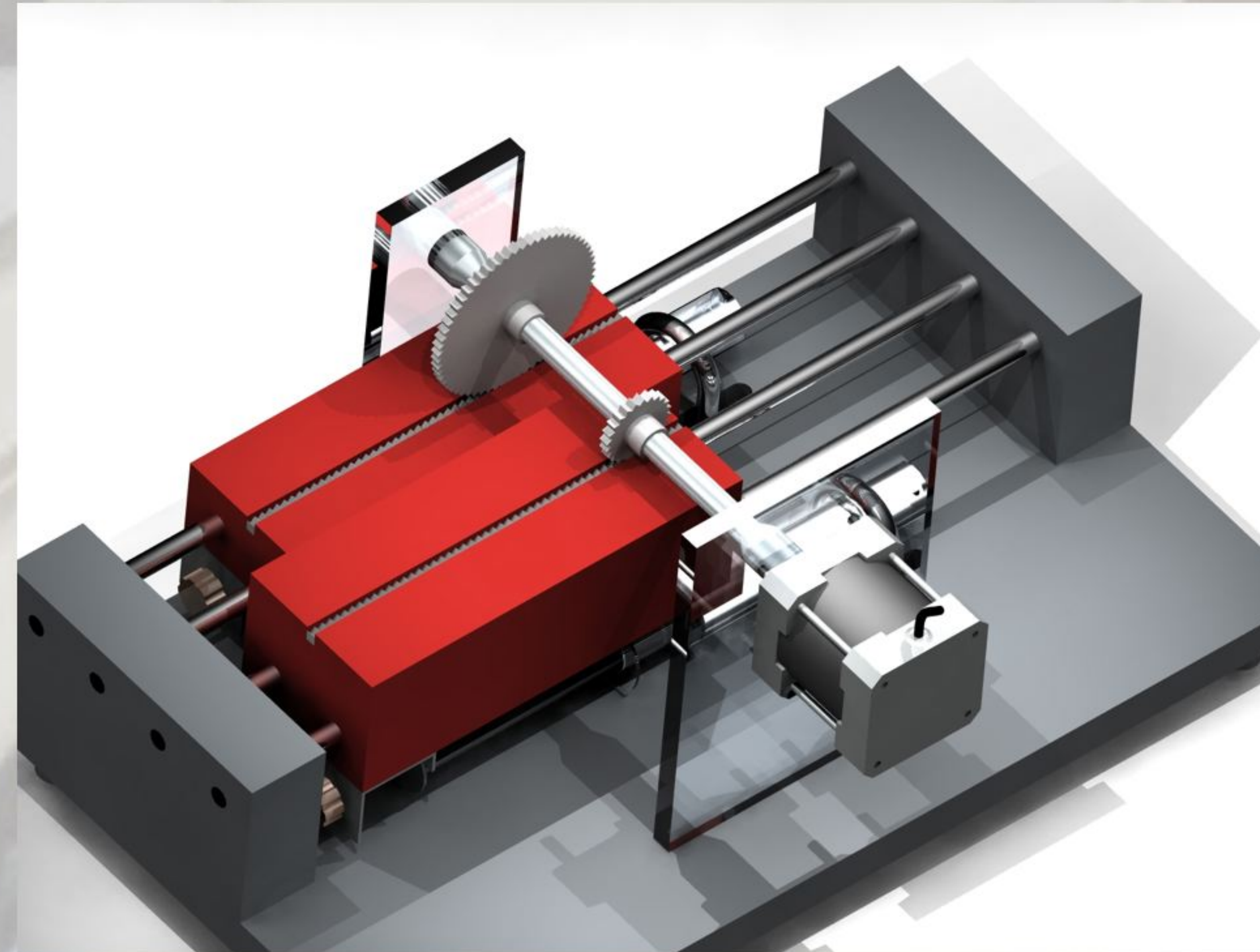
3-He MRI

- Conventional MRI scanner
 - Signal comes from Helium instead of Hydrogen
 - Helium is inhaled
 - Images allow non-invasive analysis of respiratory function and structure



Human lung images taken using ³He MRI [1]

Original Design



Design Improvements

Materials

Nylon-66 over HDPE for bulk pieces

- Increased wear resistance and decreased friction for sliders
- Harder – less compliance, easier to machine
- Cheap compared to similar materials (Delrin™)

Aluminum over stainless steel for axle

- Non-ferrous
- Faster machining

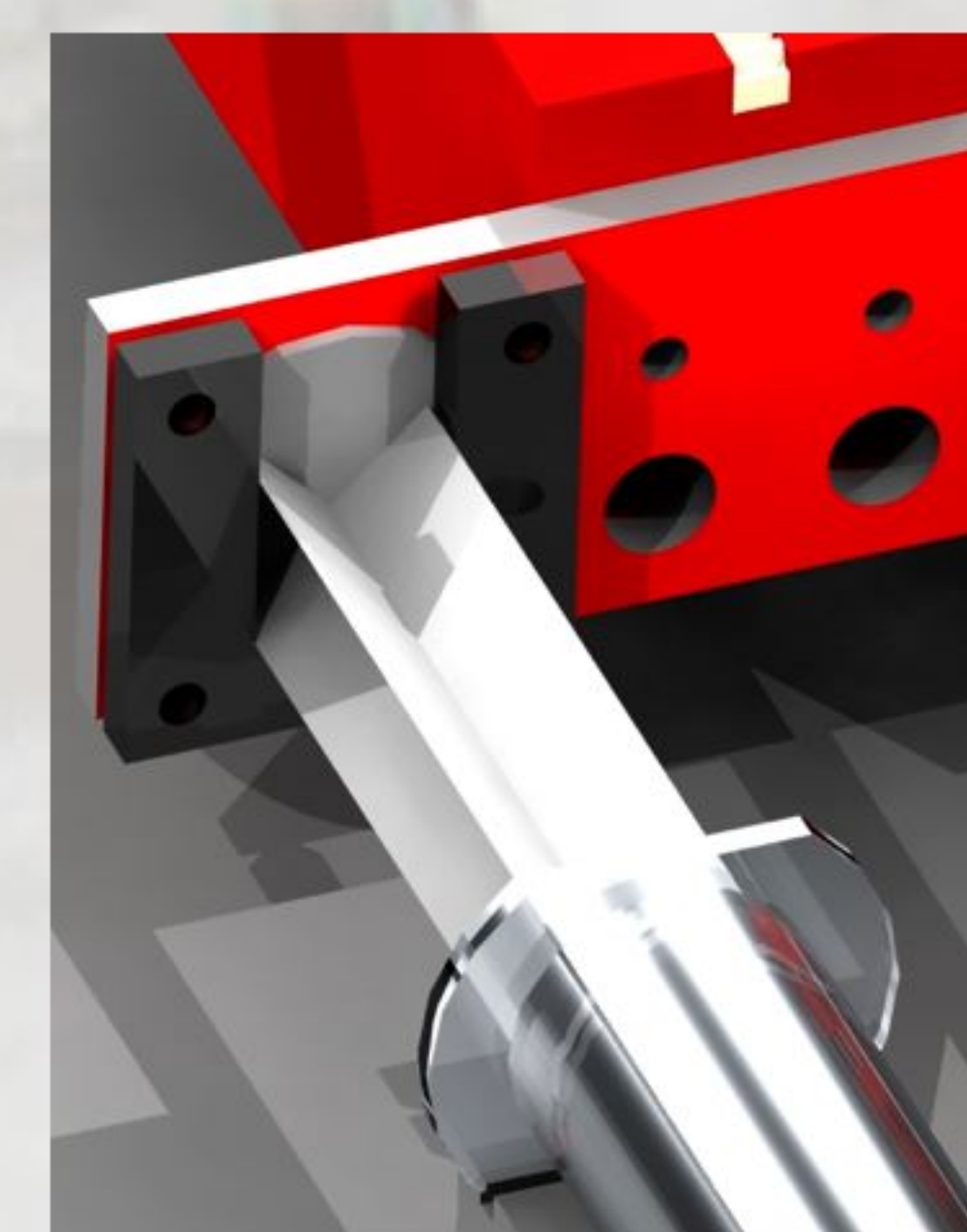
Slider Design

Shape and size

- Syringes relocated to sides for easier access
- Smaller – reduce overall size of device, maintain full range of motion for plungers

Plunger clips

- Eliminates “flexing” found in old design
- Interchangeable plates allow for different syringe sizes
- Force on plunger in same direction as motion
- More closely mimics push/pull forces of a human hand



Valve Timing

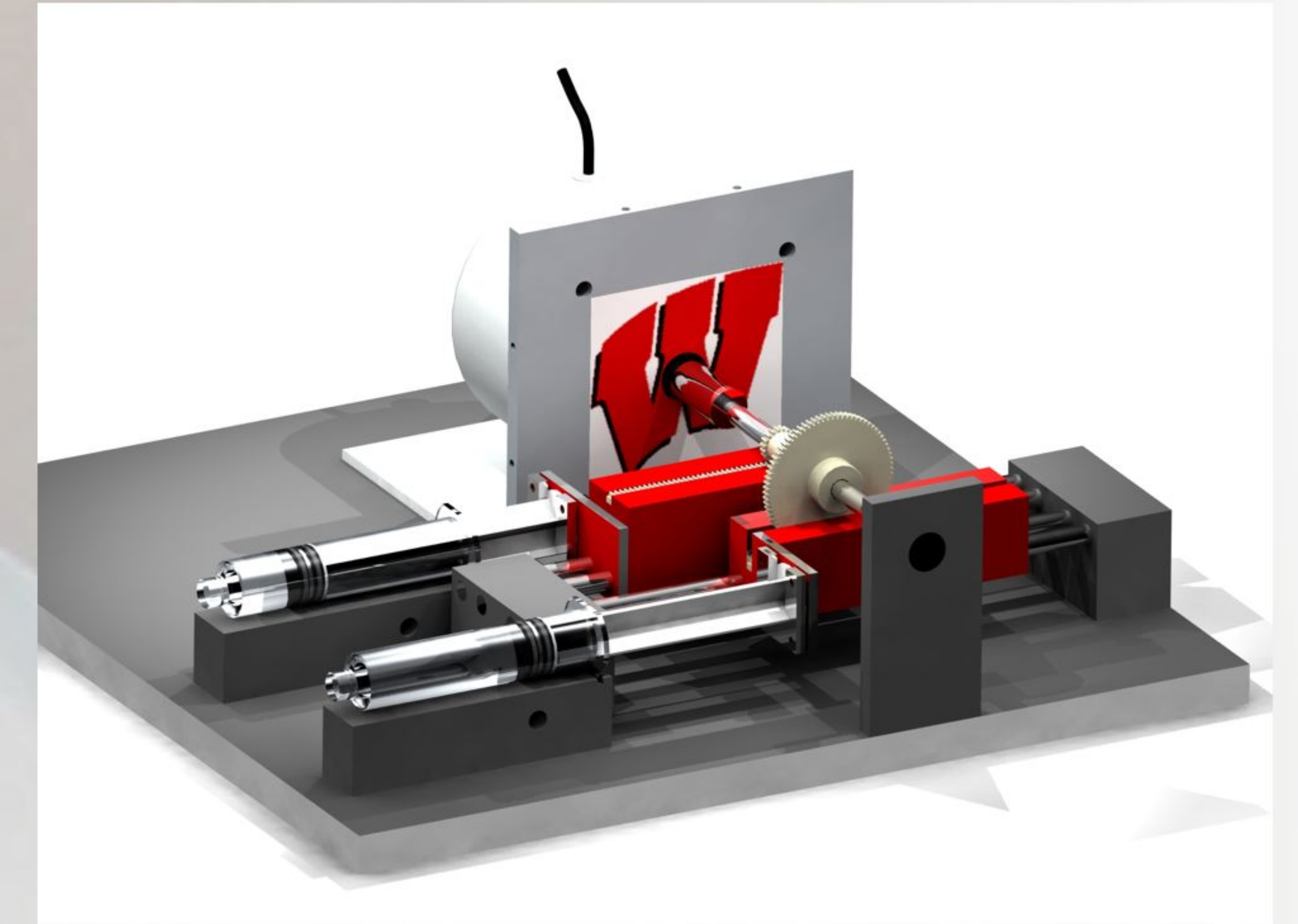
Alternating O₂ and ³He delivery

- (Problem) Valves produce O₂ “chaser” after ³He breath
- Change duty cycle of ³He/O₂ selection valve timer

Simultaneous O₂ and ³He delivery

- Shut off valve 2
- Leave valve 3 on ³He

Design Improvements (Cont'd)



Motor

NEMA size 34 over NEMA size 17

- Sufficient torque with syringes in place
- New motor and controller taken from original device
- Existing shielded power cord and communication cables
- Fits both prototypes

Future Work

Prototype Testing

- Gadolinium testing within MRI coil
- Flow measurement
- Volume Measurement
- Confirm 80:20 ³He:O₂ ratio
- Imaging tubes will show where gas mixing occurs
- Test LabVIEW program
- Confirm precise Tidal Volume (TV) delivery
- Confirm precise RR
- Validate timing of pneumatic valves

Animal Testing Protocol

- Scan with 1st generation prototype
- Scan with 2nd generation prototype
- Compare scan sequence outputs
- Compare image quality
- Determine if imaging every breath is worthwhile – weighing time saved vs. image quality

References

[1] Tooker AC, Hong KS, McKinstry EL, et al. Distal airways in humans: dynamic hyperpolarized ³He MR imaging—feasibility. *Radiology*. 2003;227: 575-579.