Definition of a PPAFO

- An ankle-foot orthosis (AFO) is a device meant to assist patients with ankle or lower leg numbness, neurological damage, or muscular weakness.
- A powered AFO has recently been developed. It is capable of assisting in both dorsiflexion (pulling toes up) and plantarflexion (pushing toes down) (Fig. 1).
- The portable pneumatic AFO (PPAFO) uses compressed carbon dioxide (CO₂) to drive the assisting actuation.

Reasons for Investigation

- The longevity of the compressed CO₂ used to power the PPAFO remains a limitation (runtime of 15-20 minutes).
- Due to a high liquid CO₂ evaporation rate from the frequent cycle times of the PPAFO (~1Hz), the CO₂ bottles become very cold.
- Temperature of a gas is negatively correlated with gas density.
- Because the valves on the PPAFO actuate with a fixed volume of CO₂, a lower gas density should correspond with a decreased efficiency of the device.

Hypotheses

- Keeping the CO₂ at or near room temperature would improve bottle longevity (number of actuation cycles possible per bottle).
- A room-temperature bottle will avoid user discomfort should the individual’s skin contact the CO₂ container.

Research Plan

Experimental Setups (see Fig. 2):
- Control: The PPAFO connected by 0.74 meters of tubing to the CO₂ bottle.
- Experimental 1: The PPAFO connected by 11.28 meters of tubing to the CO₂ bottle.
- Experimental 2: The PPAFO connected by 0.74 meters of tubing to the CO₂ bottle, which is submerged in room-temperature water.

Trial Length:
- The PPAFO ran off one 20 oz. bottle of CO₂ until it could no longer dorsiflex (pull the foot up).
- A “step” was a single plantarflexion or dorsiflexion actuation (i.e., 2 “steps” = one actuation cycle).
- The mass of the CO₂ at the start of the trial was recorded.

Future Experiments

- To understand the state of the CO₂ at each component of the PPAFO.
- Investigate the benefits of heating the system above room temperature.
- Pursue an implementation of a portable lightweight heat exchanger.

Acknowledgements

This research was funded by the Center for Compact and Efficient Fluid Power, NSF grant number 0540834.