PRESSURE-RESISTING FERROFLUID PLUG

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This project seeks to create a non-rigid fluid electromagnetically powered plug.

OBJECTIVE

Determine the best method (solenoid or horseshoe magnet) to create a ferrofluid plug to resist pressure using a variety of electromagnetic geometries

MOTIVATION

Understanding efficient ways to resist fluid pressure with a ferrofluid plug, a component of fluid handling systems, such as valves and pistons, to determine practical ways to handle the fluid.

BACKGROUND AND VARIATIONS

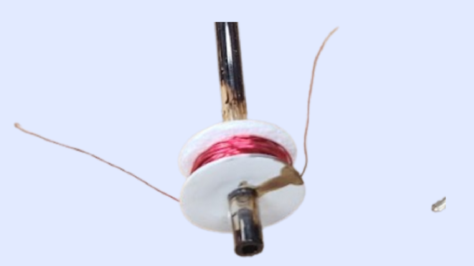


Figure 1: 26 AWG copper wire was wrapped around 3D printed spools to create a simple 1.3 ohm electromagnet.

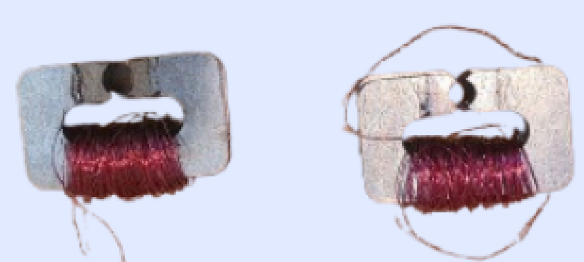


Figure 2: 2 0.25" blocks of steel were cut into C-shapes and glued together to create the electromagnetic core wrapped with 26 AWG copper wire to create 3.3 ohm electromagnet.

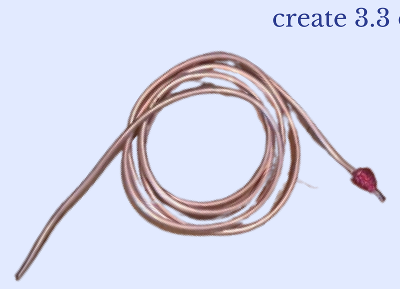


Figure 3: 26 AWG copper wire was wrapped around OD 4mm and ID 3 mm soft copper pipe to create 3 ohm electromagnet

HYPOTHESIS

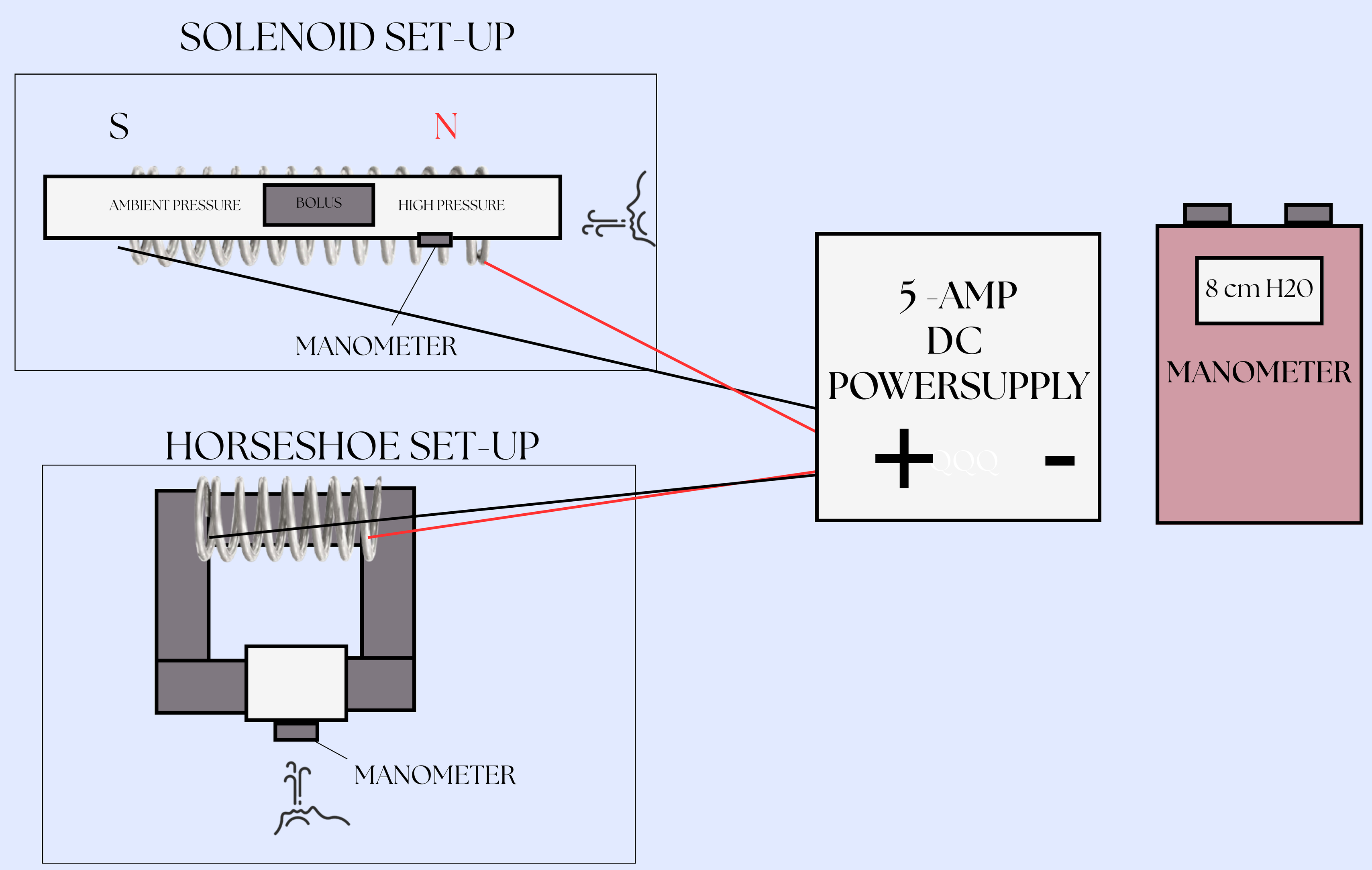
Solenoids are expected to perform better than the horseshoe magnet.

APARATUS AND INSTRUMENTATION

Figure 4: Instrumentation used in the experiment above. From left to right, Naweisz bench DC power supply, EHDIS manometer, and Kaiweets multimeter shown above.

A Naweisz bench 5-amp DC power supply was used to power the electomagnets. The Kaiweets multimeter was used to measure the resistance of the electromagnets. Finally the EHDIS manometer was used to measure the pressure held by the ferrofluid plug

EXPERIMENTAL SET-UP



EXPERIMENTAL METHOD

1. The electromagnet was connected to a DC bench power supply.
2. The manometer was connected to measure the air pressure held by the plug.
3. The voltage was slowly increased at 30 sec intervals until the magnet was hot to the touch.
4. Then air was blown into the set-up until the plug collapsed.
5. The manometer reading at the highest point was recorded as the pressure at failure.

LIMITATIONS

The solenoid spools were 3D printed from originally PLA and then nylon but would melt at higher powers, limiting the current that could be applied to the electromagnets.
(In the horseshoe set up the enclosure created an airtight channel for the plug.
The enclosures were printed in resin and did not get as hot. Due to this, they were not a limitation in the set up.)

RESULTS

	Amperage (Amps)	Ampere-turns (At)	Failure Pressure (cm of H2O)
80 Turn Solenoid (trail 1)	3.71	296.8	5.4
80 Turn Solenoid (trail 2)	3.86	308.8	5.4
160 Turn Solenoid (trial 1)	5.53	884.8	6.6
160 Turn Solenoid (trial 2)	2.37	379.2	7.6
Large Diameter Horseshoe	2.86	457.6	0.1
Small Diameter Horseshoe	1.84	294.4	0.3

CONCLUSION

Contrary to the initial expectations the solenoid did not perform better than the horseshoe magnet. However, our ability to draw further conclusions was limited by our control of the magnetic permeability of the steel and the shapes that we chose to test.

FUTURE STEPS

- Different shapes of steel cores will be tested and compared to determine the strongest core shape.
- Testing an electromagnet with a steel rod core inside the solenoid-wrapped tube to expand the investigation on the effect of cores on electromagnet strength.
- Creating a custom magnetic core from epoxy and ferrous powder will be tested.
- Improve the visibility of the horseshoe magnet setup to allow easier observation of the bolus.

If promising results are found, we would attempt to identify a mathematical model that relates ampere-turns on the electromagnet to pascals of pressure. This would include exploring scaling the system down for small-scale applications like microchips.