Liquid Property Control Unit

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Introduction

The Liquid Property Control Unit (LPCU) was designed to make the process of changing the fluid characteristics of the liquid in a mock circulatory loop (MCL) faster, more accurate, and autonomous. Using three different base fluids (water, water:glycerin, and a saturated NaCl solution), the LPCU drains and adds fluid to the MCL to achieve the desired fluid characteristics. Fluids are drained and added using Bartendro peristaltic pumps. The user interacts with a graphical user interface (GUI) made with MathWorks MATLAB (Figure 1). The user simply inputs the current viscosity and density of the fluid in the MCL, the desired characteristics, and the volume in the loop. The user will be given an estimated run time and is notified of the LPCU's progress throughout the operation.

Materials and Methods

- The LPCU is controlled with an Arduino Mega 2560 Microcontroller coded with the Arduino IDE (Figure 2) which calculates run times for the pumps and triggers the solenoid valves
- Bartendro peristaltic pumps are used to pump fluid to and from the MCL
- The Arduino controls a relay that triggers three solenoid valves which select the solution to be pumped into the MCL
- The three base fluids that compose the final mixture in the MCL are pure distilled water, a 60:40 Glycerin:Water mixture by weight, and a saturated NaCl solution
- The Arduino is controlled with a GUI built in MathWorks Matlab
- To verify the properties of base fluids and test trials, a balance (Figure 3), a Fenske viscometer (Figure 4), and an Atago refractometer (Figure 5) are used.

Figure 3: Precision Scale

Figure 4: Fenske Viscometer

Figure 5: Refractometer

Results

In order to validate our methods of measurement, I created 3 mixtures with known characteristics and measured the viscosity and density of those mixtures (Table 1). It was during this process that I discovered the Fenske viscometer has an effective range of 2.0-7.5 cSt.

Table 1: Results validating the process of determining density and viscosity. "Theoretical" values were obtained from References 1 and 2.

	Theoretical Density	Measured Density	Theoretical Viscosity	Measured Viscosity
40/60 glycerin/ water	1.11	1.12 g/mL	3.12 cSt	3.14 cSt
50/50 glycerin/ water	1.14	1.16 g/mL	4.98 cSt	4.94 cSt
60/40 glycerin/ water	1.26 g/mL	1.25 g/mL	8.72 cSt	7.9 cSt***

Figure 1: GUI made in MATLAB. User inputs current and desired characteristics into the fields on the right. Then, the operator inputs the COM port number and clicks connect. Then, the user simply clicks run. The estimated run time will be displayed, along with the status of the pumps (Ready, Draining, or Pumping). When finished, the GUI will display the properties of the of the current mixture for easy reference.

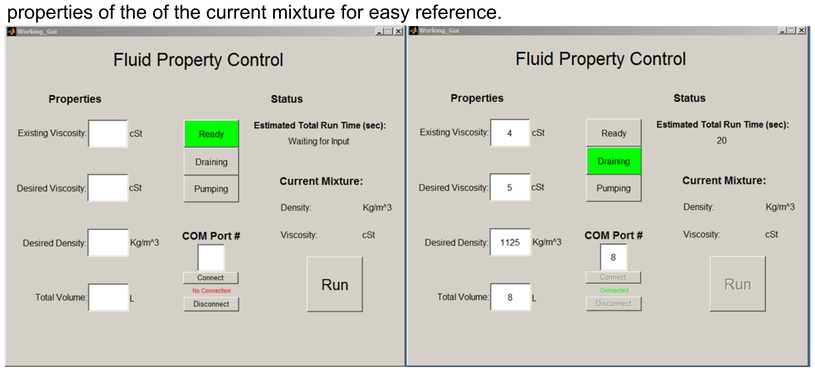
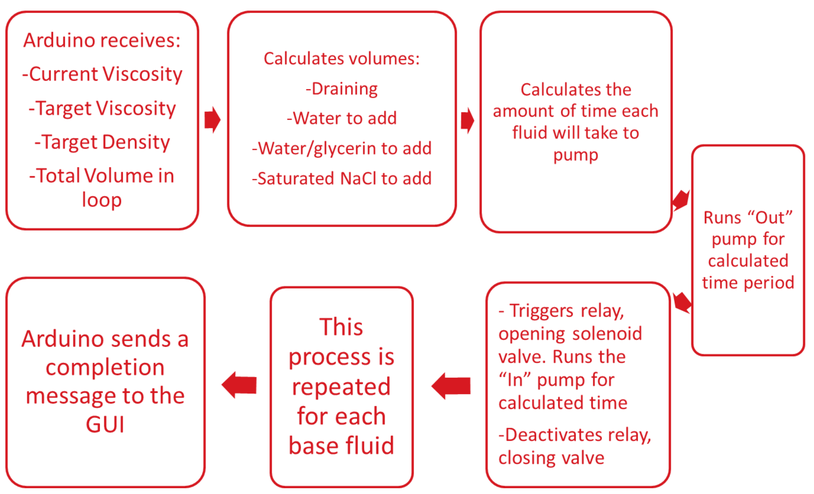


Figure 2: Code Flow Diagram



The results of the first test trials of The LPCU are shown in Table 2. The LPCU dispensed the correct volume of liquid but did not achieve the target characteristics.

Table 2: The Initial properties are the properties of the mixture before the property change, The target is the characteristics inputted into the GUI. The Final are the measured characteristics of the fluid in the container after the fluid change.

	Initial		Target		Final	
	Density	Viscosity	Density	Viscosity	Density	Viscosity
Container 1	1.102 g/mL	2.81 cSt	1.125 g/mL	3.5 cSt	1.114 g/mL	3.52 cSt
Container 2	1.104 g/mL	3.00 cSt	1.125 g/mL	4 cSt	1.252 g/mL	3.86 cSt
Container 3	1.103 g/mL	3.17 cSt	1.125 g/mL	4 cSt	1.119 g/mL	3.83 cSt

Conclusions

Further calibration is necessary in order to achieve the desired results. The LPCU has maintained a constant volume in the test containers, demonstrating that it is accurately pumping the volumes requested by the Arduino. The volumes that were requested were verified by hand, meaning that the Arduino was calculating the correct volumes, but the base fluids were inaccurate. There were issues with the NaCl not dissolving or collecting at the bottom of the pale when the temperature would fluctuate in the lab, making the mixture less dense.

Future Research

Future work with the LPCU will be to utilize the system as a means of controlling different types of mixtures of base fluids that will be investigated for use as a blood analog in fluid dynamics experiments evaluating medical device performance.

References

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