Liquid property control system for LVAD ISO 5198 testing and mock circulatory loop simulations.

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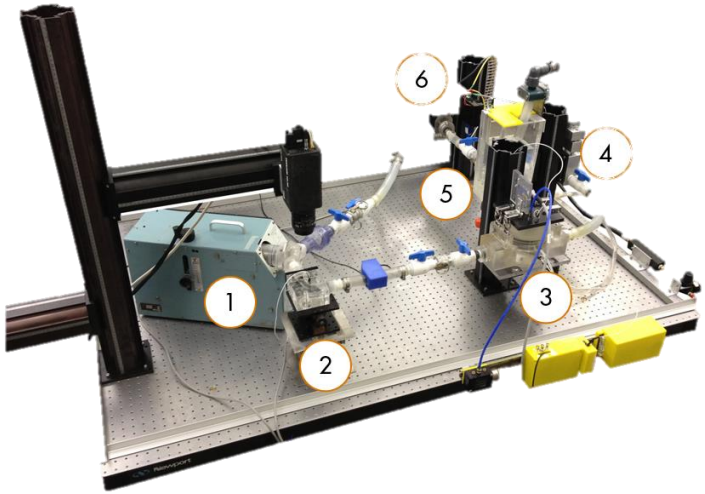
Outline

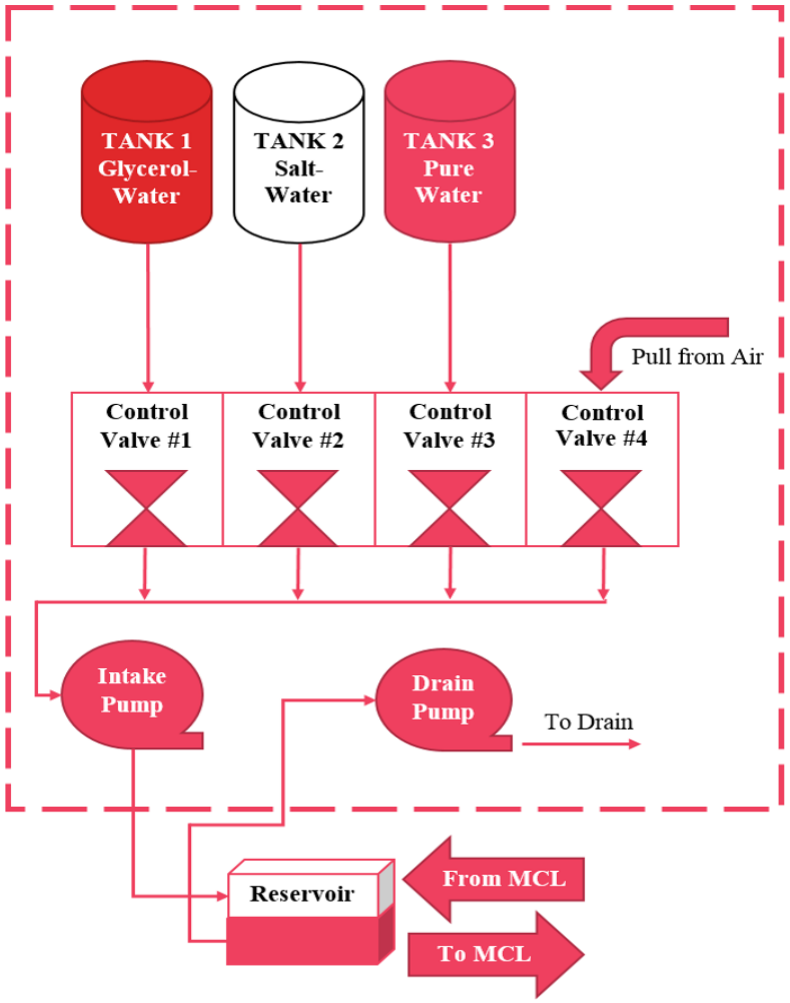
- What was the Liquid Property Control Unit (LPCU) designed for?
- Design and structure of the unit
- Methods and materials for the operation of the unit
- Overview of the program that governs the operations of the LPCU
- Methods and materials used for collecting the results
- Results
- Conclusions
- Future work

Background

- Mock circulatory loops (MCLs) test viability of LVADs
- Blood viscosity and density varies so LVADs must be tested at a range of viscosities and densities to ensure safety
- Previously, the liquid in MCLs were changed by hand
- LPCU allows for round-the-clock scheduling of simulations and simplistic means of documenting changes



LPCU Design Overview



Refutas Equation

$$VBN = 14.534 \ln[\ln(v + 0.8)] + 10.975$$

$$VBN_{Blend} = (X_A \times VBN_A) + \cdots + (X_N \times VBN_N)$$

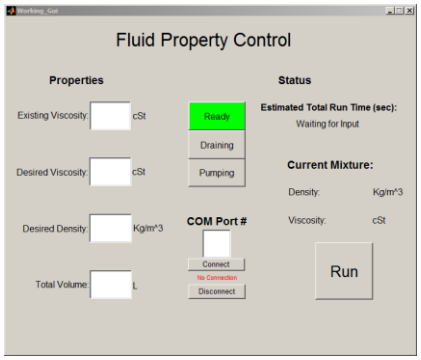
$$v = \exp\left[\exp\left(\frac{VBN_{Blend} - 10.975}{14.534}\right)\right] - 0.8$$

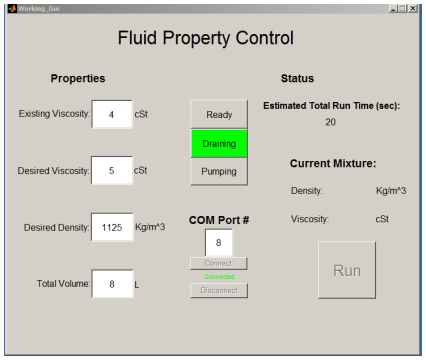
$v = Viscosity$

$VBN = Viscosity\ Blending\ Number$

Materials and Methods for Construction of LPCU

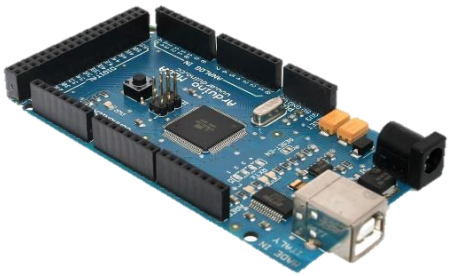
- A Graphical User Interface (GUI) made with MathWorks Matlab sends user input to the Arduino

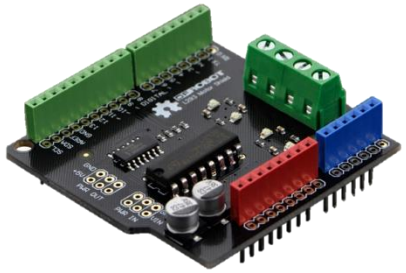


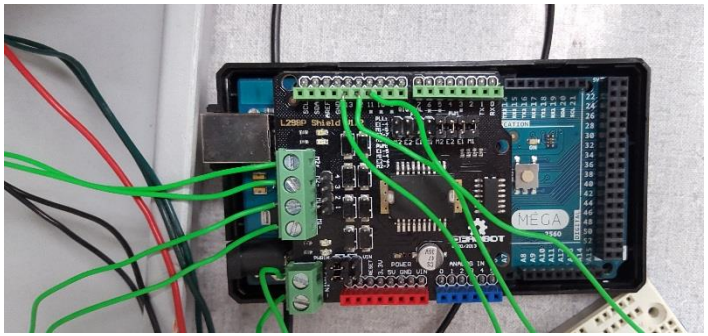


MathWorks®

- An Arduino Mega 2560 with a DFRobot motor shield computes the liquid to be dispensed and controls the pumps

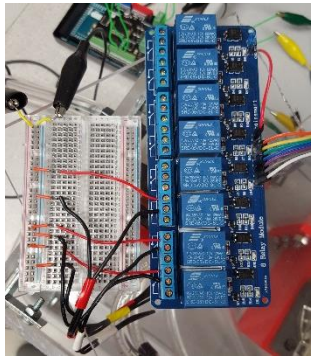






Materials and Methods

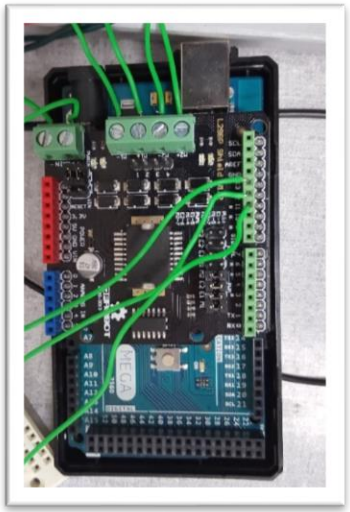
- Fluids are pumped into and out of the loop with Bartendro peristaltic pumps
- A relay system activates solenoid valves that allow for all three base liquids to be drawn through the same pump
- The three base fluids stored in plastic pales:
  - 60:40 glycerin-water mixture by weight
  - Pure distilled water
  - Saturated NaCl mixture



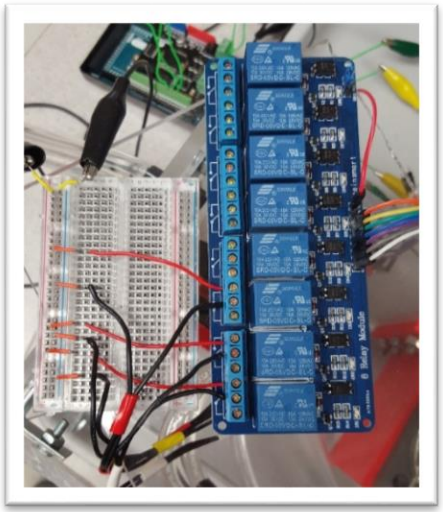
Design of the LPCU

Pumps and valves

Arduino with motor shield

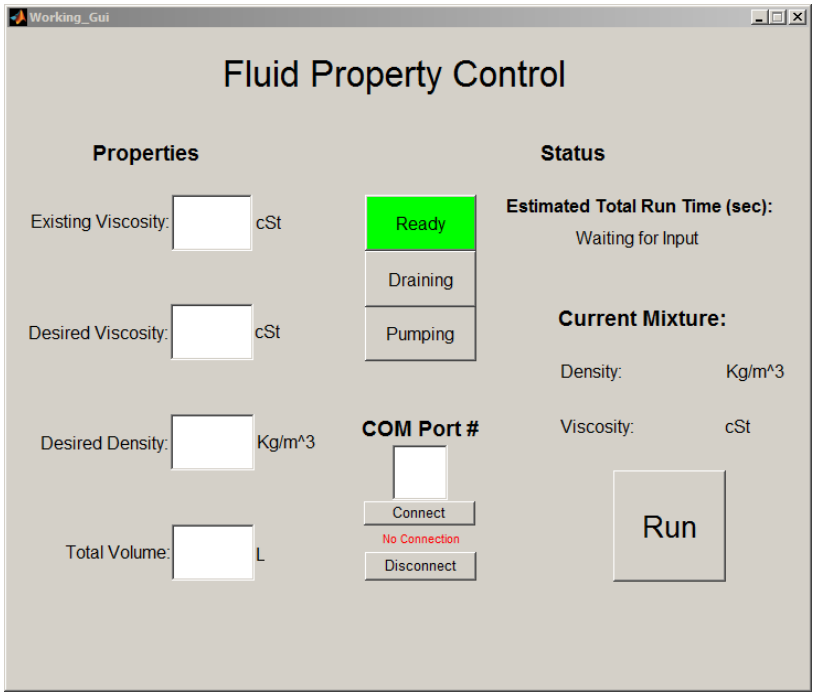


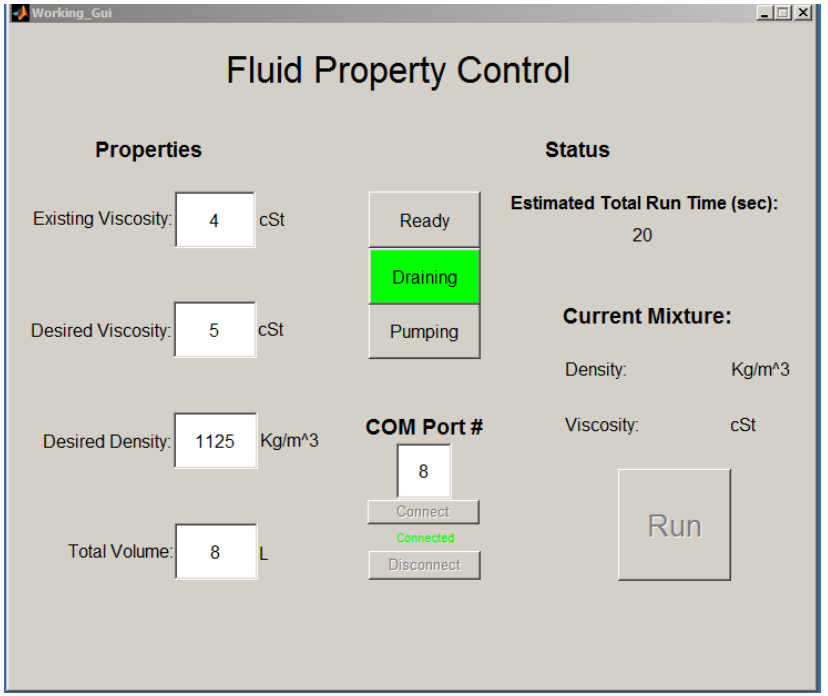
Relay system



Base liquids

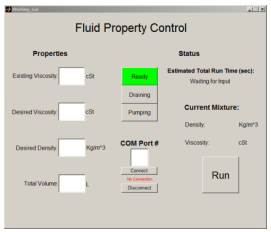
Graphical User Interface

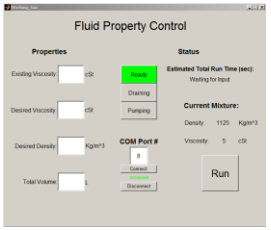




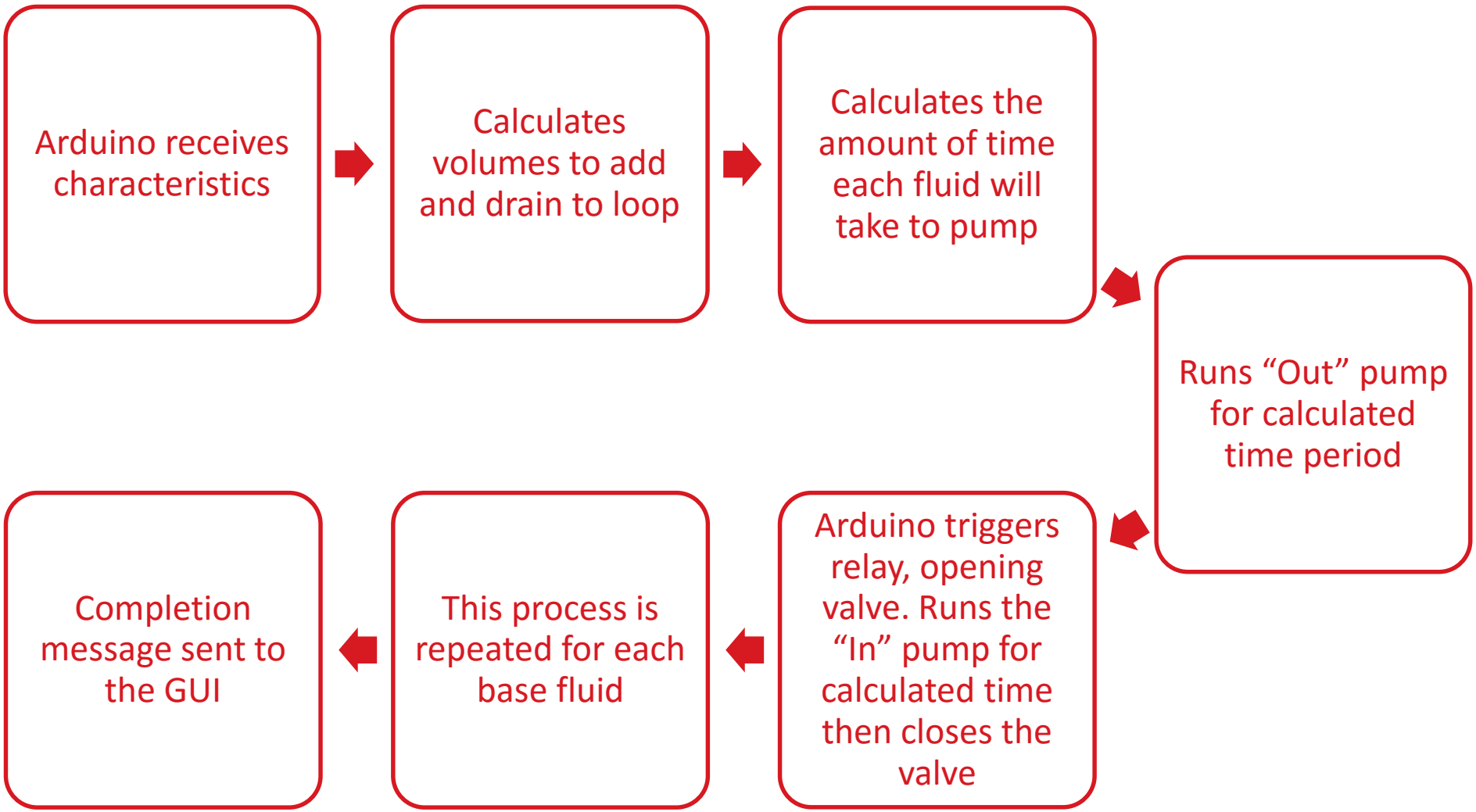
How the LPCU is Used

User inputs characteristics into GUI → Arduino receives input and calculates necessary volumes → Pumps remove fluid from MCL → Pumps add volumes of base fluids to MCL → User notified that property change is complete



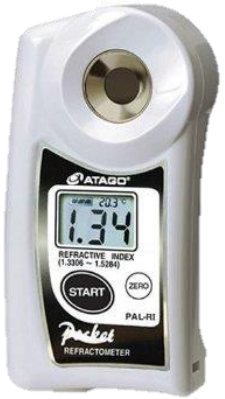


Arduino Code Flow Diagram



Materials and Methods for Verifying Results

- Samples of the resultant fluid are taken using a volumetric pipette and stored in glass vials
- A balance is used to verify the density of the sample
- A pocket refractometer is used to verify the refractive index of the sample
- A viscometer is used to verify the viscosity of the sample



Results

- Using the instruments on the previous page, confirmed the properties of 3 known mixtures
- Density and viscosity of glycerin/water solutions
  - 40/60 glycerin/water
  - 50/50
  - 60/40

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

Results

- 3 containers with a glycerin water mix were made
- It was determined that the LPCU accurately dispenses the volume of desired fluids as measured in a graduated container

	Initial		Target		Final	
	Density	Viscosity	Density	Viscosity	Density	Viscosity
Container 1	1.102 g/mL	2.81 cSt	1.125 g/mL	3.50 cSt	1.114 g/mL	3.52 cSt
Container 2	1.104 g/mL	3.00 cSt	1.125 g/mL	4.00 cSt	1.252 g/mL	3.86 cSt
Container 3	1.103 g/mL	3.17 cSt	1.125 g/mL	4.00 cSt	1.119 g/mL	3.83 cSt

Discussion

- The Arduino is correctly calculating the fluid to be drained and added
- Arduino accurately dispenses the amount of each fluid that the Arduino requests
- The accuracy of the base fluids is the main concern at this point
  - Slow separation of water/glycerin mixture
  - Unreliable density of NaCl mixture from temperature changes
  - Mold developing in liquids over time

Conclusion

- The LPCU is well on it's way to being fully operational and only minor adjustments need to be made to the base fluids
  - Constant stirring
  - Working to keep temperature constant
  - Using UV lights to kill bacteria
- Designed to be easily customizable and can be used for other applications

Future Direction

Short Term Goals

- Further work with base fluids to ensure accuracy of the final mixture
- Improving the GUI to better inform the user on the status of the Unit and document liquid changes

Long Term Goals

- Shear thinning

Thank You

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