Hemodynamic Simulator II

P09026

Preliminary Design Review

10/3/2008

Rochester Institute of Technology

Contents

Project Plan

Project Summary

06Project #	Project Name	Project Track	Project Family
P09026	Hemodynamic Flow Simulator II	Biomedical Engineering	
Start Term	**Team Guide**	**Project Sponsor**	**Doc. Revision**
2008-1	Dr. Phillips	Dr. Phillips	1.3

Project Description
Hemodynamic Flow Simulator is a modular system that replicates the flow and pressure related to the hemodynamic system. The long term goal of this project is to analyze and redesign some of the features of the module and make it fully compliant to customer's needs. The prototype designed by project P08026 team would be utilized in an attempt to achieve a final unit which is both self contained and aesthetically pleasing. In addition, the module should be able to perform in equally well, in educational and research applications.

Problem Statement:
The primary objectives of this project are to redesign the pump to its initial requirements, redevelop the data acquisition software and develop computer control for all system parameters. In addition, the final product must be self contained, and easy to transport from one classroom to another.

Objectives/Scope:

1. Initially, the pump must be redesigned in order to better replicate the pumping of the heart, which includes appropriate blood pressure and volume from the heart.
2. The final product must contain a data acquisition system that would monitor blood pressures, volumes, flow rates at desired locations. In addition, the measured data must be easily accessible to the user.
3. Furthermore, develop a computer system that would allow a user, access to all the parameters of the flow simulator. Hence, providing the user with a better control of the entire unit.

Deliverables:

- To have a portable, aesthetically appealing, and fully functioning re-modeled blood flow simulator that would appropriately replicate the operations of the heart (left-ventricle).
- To have a fully remodeled Graphical User Interface that would provide users full control of the unit, and is simple to operate.

Expected Project Benefits:

- The module would provide faculty members with a tool that may be utilized for instructional purposes.
- This will soon incorporate the testing of the school's LVAD prototypes to prove their effects of the circulatory system.

Core Team Members:

- Alexander Baxter
- Joseph Featherall
- Mark Frisicano
- Clarissa Gore
- Liliane Pereira

- Jonathan Peyton
- Gaurav Zirath

Assumptions & Constraints:

1. Simulate actual flow rates and pressures as produced by the human heart.
   (ie. Match pressure waves in aorta and left ventricle, other properties to be emulated by the system include proper system resistance and compliance.)

2. Must provide electrically and mechanically safe operation.
3. Must be portable, easy to transport from one class to another.
4. Heart chamber must be easily visible and data must be clearly displayed and recorded for use.

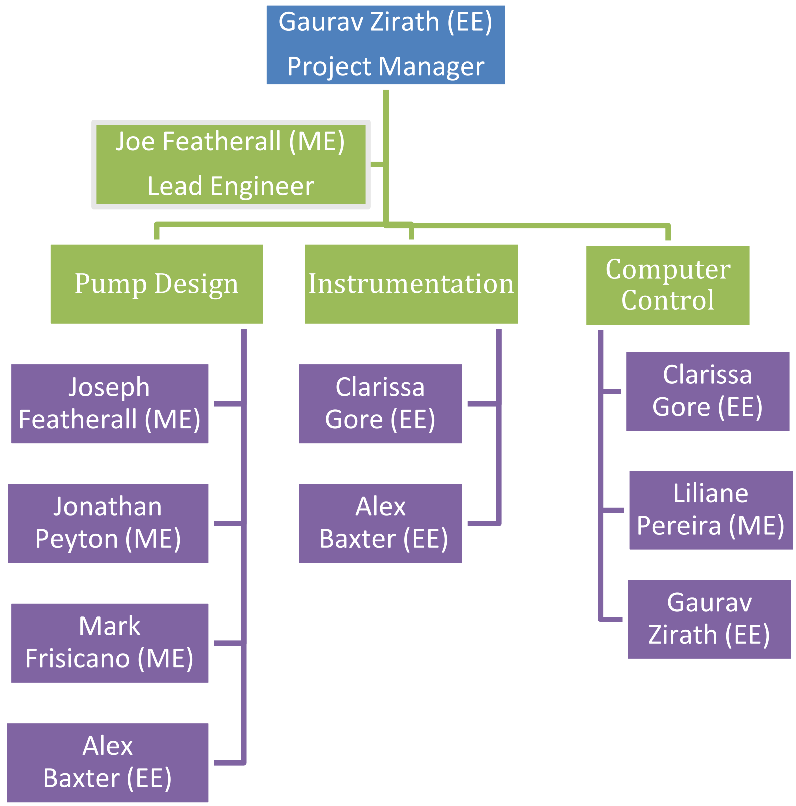
Issues & Risks:

- Redesigning the pump in an attempt to replicate the blood flow of the human heart.
- Developing a GUI that would allow user to fully control the system, including flow rates, and blood volume.

2-Quarter Schedule

	Fall '08	Winter '08
Week 1	● Become informed on the project basics ● Contact former group members ● Set tenative plans of action ● Reviewed Project with Day and Phillips ● Set design path from newly gained information	●Begin fabrication/testing/programing of subsystems
Week 2	●Develop a firm understanding of the individial components design and purpose and also the system as a whole ● Assign sub groups for design ● Set up meeting with Dr. Schwarz ● Use gianed knowledge to refine goals and engineering specs ●Create list of key issues to be fixed in the system ●Define each members role in the group ●Outline project goals ● Assigned personal tasks for the team to complete the delieverables	●Continue fabrication/testing/programming of subsystems
Week 3	●Research and reassesment of goals ● Must have atleast one meeting with Schwarz by the end of this week ● Begin meeting in sub groups and laying out the plot for progress for each subassembly ● Begin finalization of engineering spec within each group ● Report to eachother as a whole to plan for the next weeks progress ●Exteneding and updating of official timeline	●Finalize sub systems ●Final outline of projects due dates and goals
Week 4	●Further Research ●Preliminary calculations(start design) ● Price and spec out components ● Review prelimary calculations and design specs with Schwarz and Phillips ● Review as one group info gathered from advisors and alter design route as needed. ● Continue with prototype design and calculations	●Begin complete system fabrication/testing/programing
Week 5	●Have Rev 1 of new design with final calculations ●Begin defining BOM	●Continue complete system fabrication/testing/programing
Week 6	●Solidfy design of system ●Pricing components ●Preliminary order	●Final system fabrication ●Continue testing/programing
Week 7	●Solid modeling and FEA/CFD analysis	●Test/Programing
Week 8	●Print making	●Address any final mechanical issues ●Optimize programing
Week 9	●Final material acquisition	●Optimize controls
Week 10	●Begin fabrication of components	●Tear down and rebuild
Week 11	●Continue fabrication of components ●Start programing	●Final testing and re-config

Work Breakdown Structure

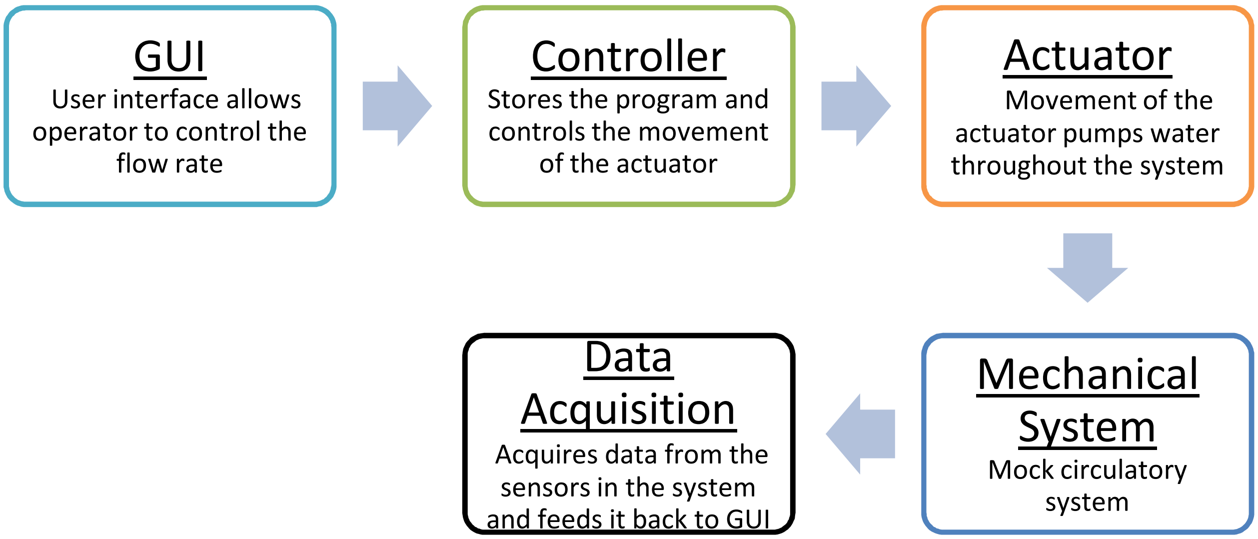


Team Roles

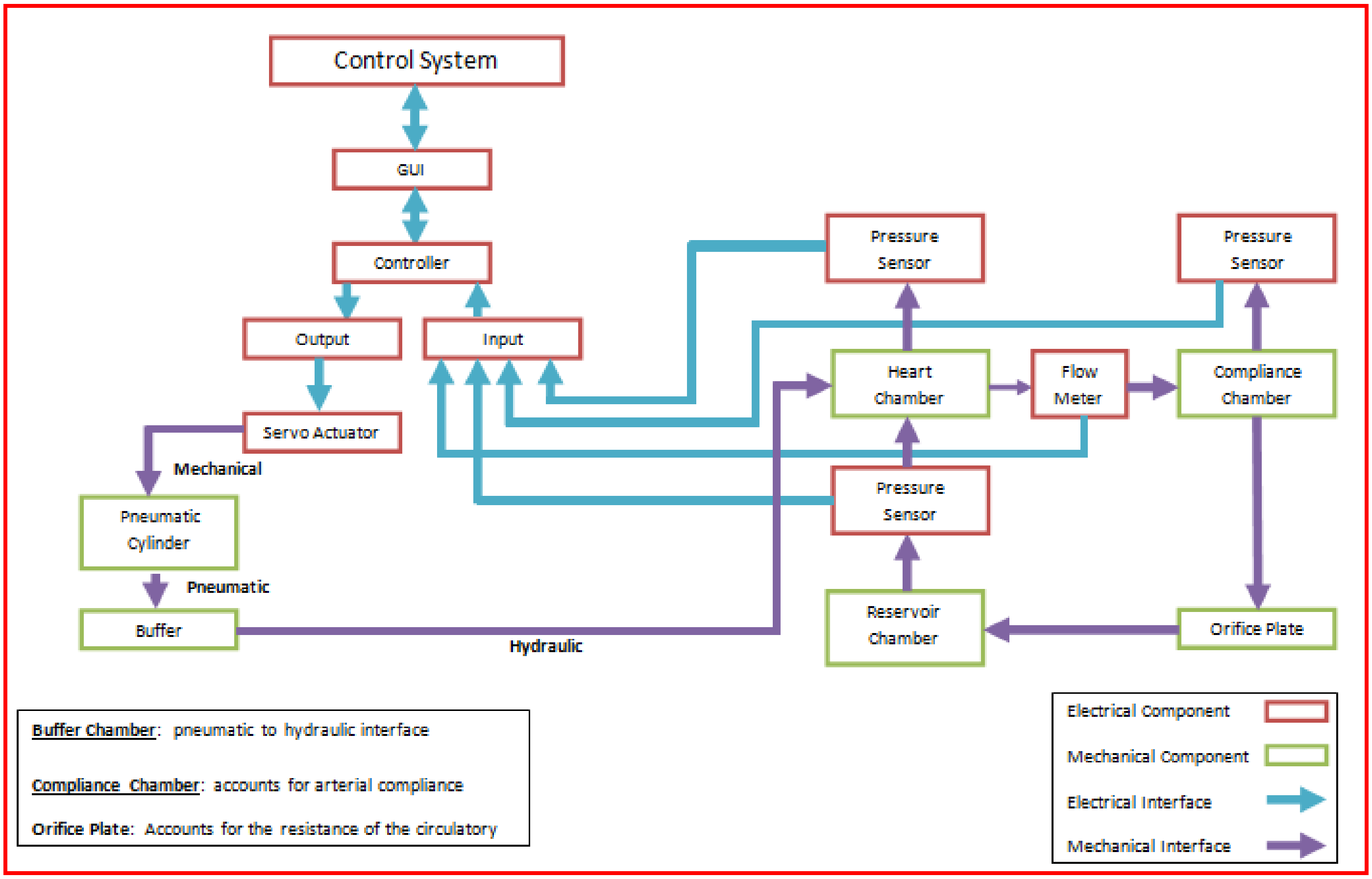
Team Member	Field of Study	Pervious experience	Role
Lillane Pereira	ME	•LabVIEW •Biomaterials •AutoCAD •Biology	Computer Control
Joseph Featherall	ME	•Impact •Frame Design •Ceramic Bearing Test •Suspension	Lead Engineer Pump Design
Mark Frisicano	ME	•Motors •Servo Motor Design •Test Rigs	Pump Design
Jonathan Peyton	ME	•Layout and Planning •Design Review •Organizing Tooling •Generator Drive	Pump Design
Gaurav Zirath	EE	•Research and Development •Programming •Transmission Line Theory	Project Manager Computer Control
Alex Baxter	EE	•Drive Control •PLC Programming •Circuit Theory	Instrumentation Pump Design
Clarissa Gore	EE	•Analog Circuit Design •Device Characterization •Technical Writing	Instrumentation Pump Design

System Level Design

Overall System Architecture



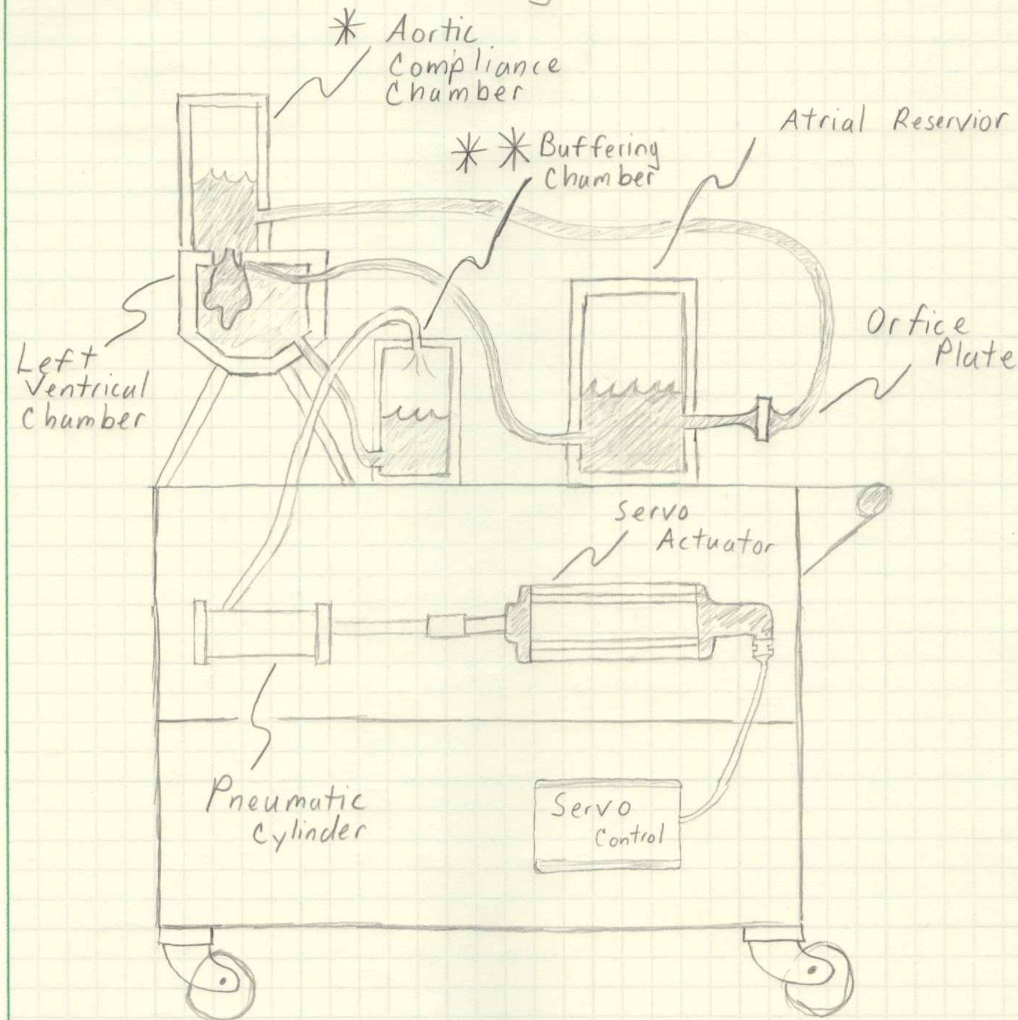
Electrical & Mechanical Model



Overall System Sketch

Joe Feathercall | P09026 | 9-19-08

Mechanical Design Sketch Rev. 2



* Aortic Compliance Chamber - moved closer to Ventrical Outlet to minimize losses

** Buffering Chamber Added to prevent bubbles from interfering w/ ultrasound

Engineering Analysis

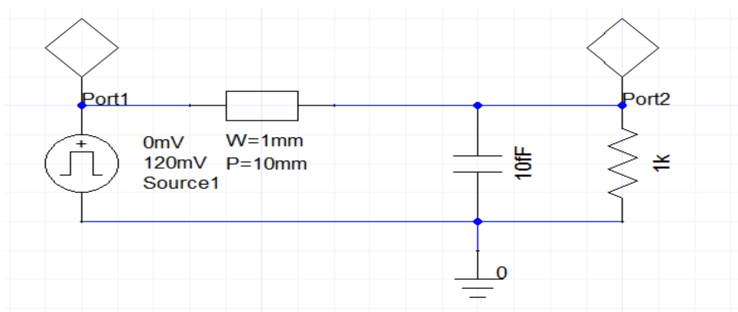
Equivalent Electrical Model

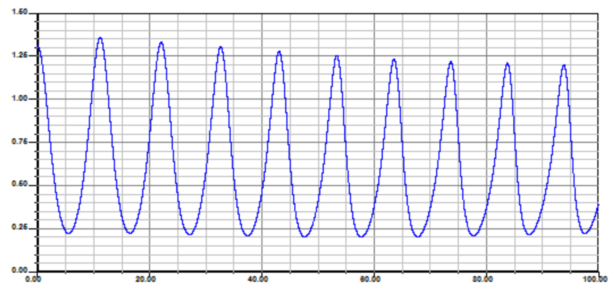
Hemodynamic Transmission Line Modeling Summary

Research has shown that the hemodynamic system can be modeling by a single two-port transmission line. Electrical parameters can be matched to analogous mechanical parameters.

- Voltage –Pressure
- Current –Flow
- Capacitance – Compliance
- Electrical Resistance – Mechanical Resistance

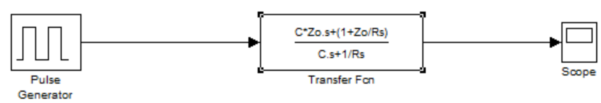
Ansoft Designer Analysis





MatLab Analysis

The transfer function of the system was computed using the Fourier Transform and simulated using Matlab.

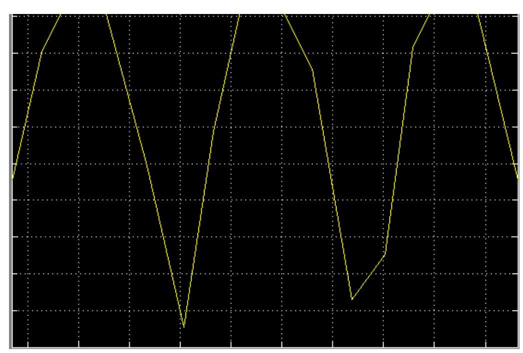


$$C\frac{dp}{dt} + \frac{1}{R}p = Q\left(1 + \frac{Zo}{R}\right) + ZoC\frac{dQ}{dt}$$

$$C(s)P(s) + \frac{1}{R}P(s) = Q(s)\left(1 + \frac{Zo}{R}\right) + ZoC(s)Q(s)$$

$$P(s)\left[Cs + \frac{1}{R}\right] = Q(s)\left[\left(1 + \frac{Zo}{R}\right) + ZoCs\right]$$

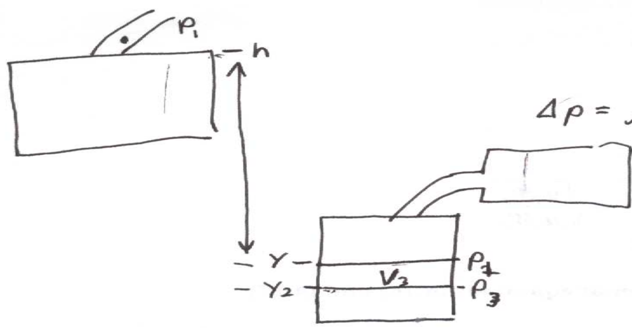
$$\frac{P(s)}{Q(s)} = \frac{\left(1 + \frac{Zo}{R}\right) + ZoCs}{Cs + \frac{1}{R}}$$



Concerns about the accuracy/usefulness of these modeling techniques:

- Does it model the system we have?
- Are we capable of adding all the necessary components?
- Will we be able to accurately map our mechanical to our electrical parameters?

Static Fluids (Level 1) Calculations



80mm hg

$\Delta p = \rho g h$

$P_d + \rho g h$

$P_s + \rho g h_2$

$PV = NRT$

$PV = PV$

$V_1 + V_3 = V_2$

$P_1 V_1 = P_3 V_2$

$P_1 V_1 = P_3 (V_1 + V_3)$

$V_1 P_1 = V_2 P_2$

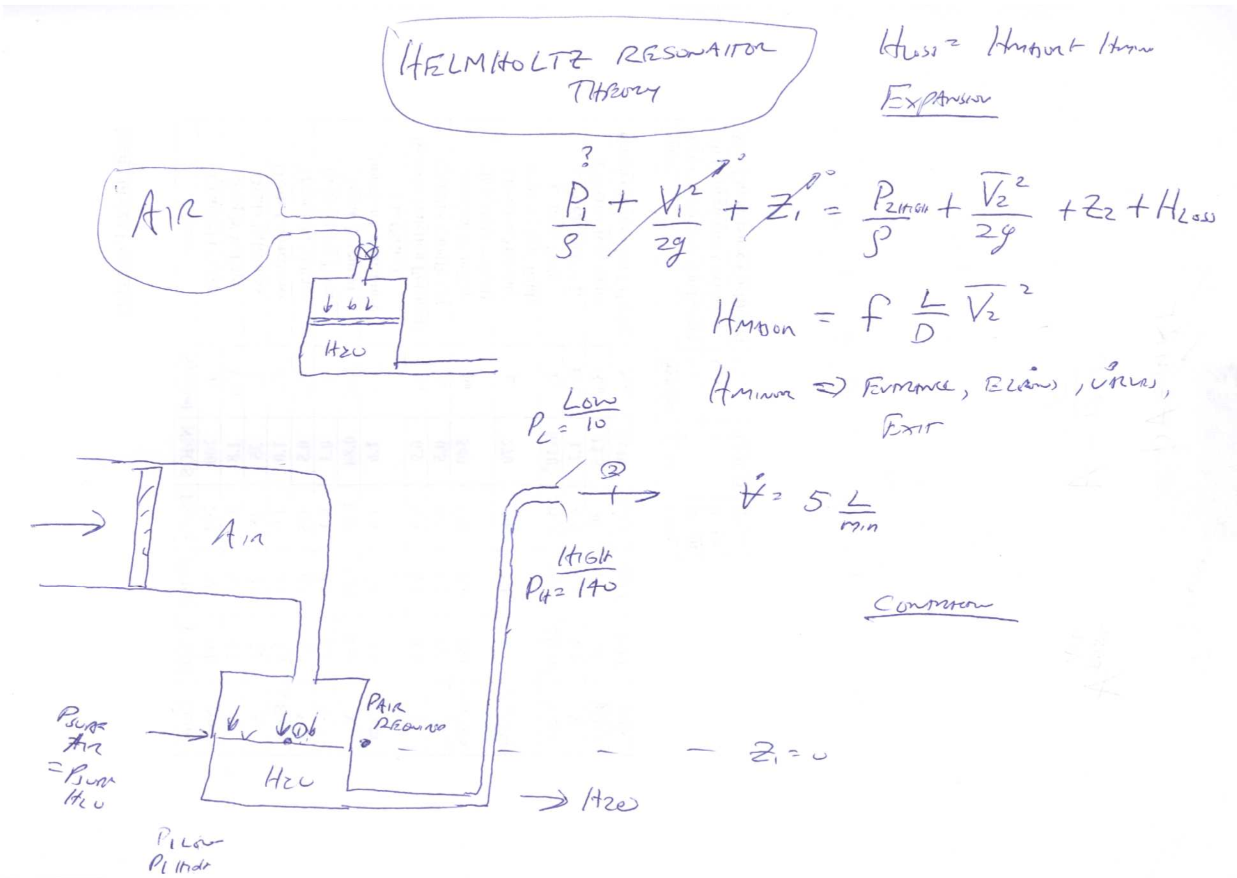
$V_1 = \frac{V_2 P_2}{P_1}$

P_2

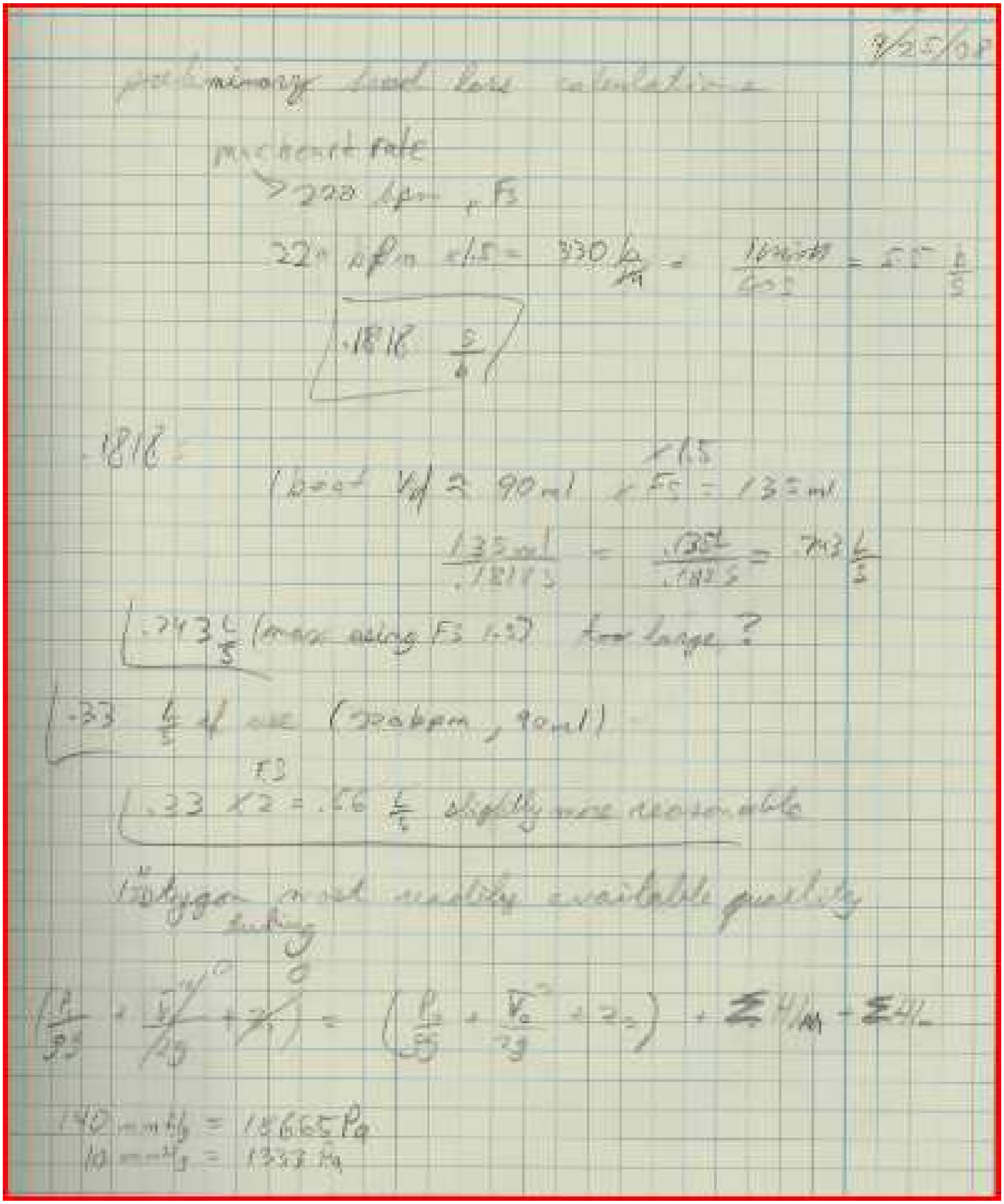
P_3

$V_2 \; P_2$

Dynamic Fluids (Level 2) Calculations



Circulatory System Analysis



9/25/08

preliminary head loss calculations

max heart rate

> 220 bpm, FS

220 bpm × 1.5 = 330 b/m = 1 beat / 60 s = 5.5 b/s

.1818 s/b

.1818 =

1 beat V_d ≈ 90 ml × FS (×1.5) = 135 ml

$\frac{135\ ml}{.1818\ s} = \frac{.135\ L}{.1818\ s} = .743\ \frac{L}{s}$

.743 L/s (max using FS 1.5) too large?

.33 L/s at rest (200bpm, 90ml)

.33 × 2 (FS) = .66 L/s slightly more reasonable

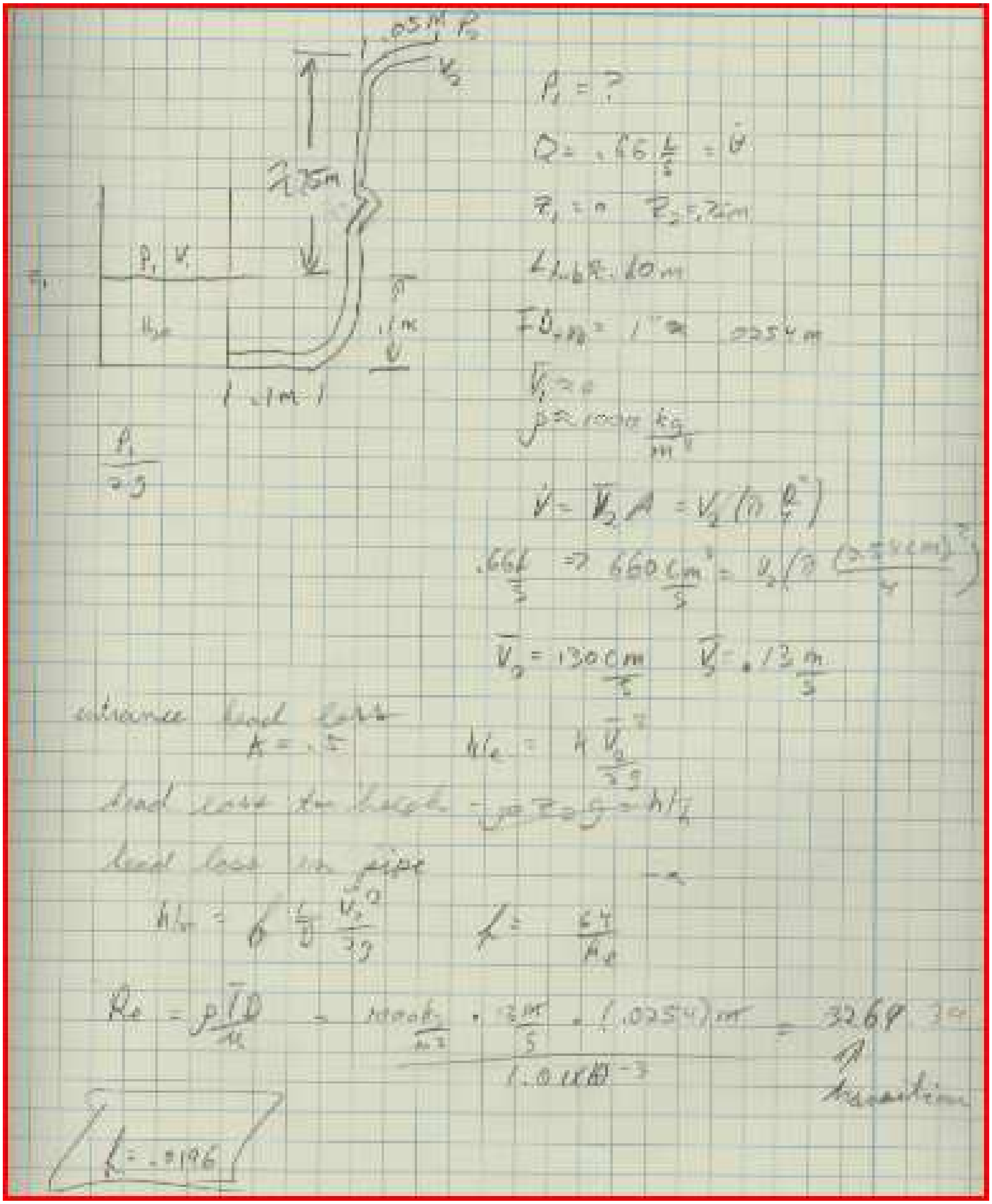
Tygon is not readily available quality tubing

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \left(\frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2\right) + \Sigma H_M + \Sigma H_L$$

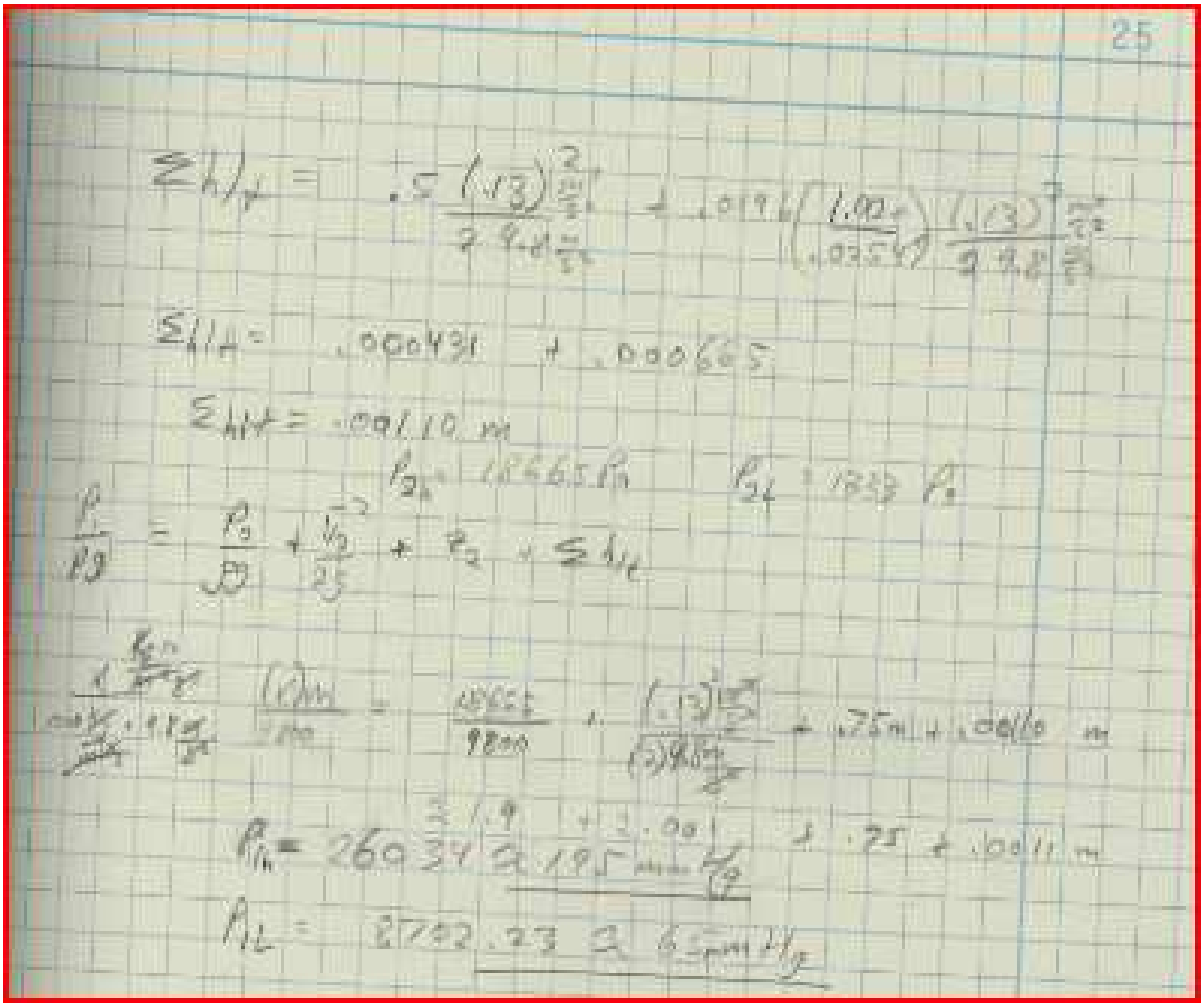
140 mmHg = 18665 Pa

10 mmHg = 1333 Pa

Circulatory System Analysis



Circulatory System Analysis



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$$\Sigma h_{lt} = \frac{.5\,(.13)^2\,\frac{m^2}{s^2}}{2 \cdot 9.8\,\frac{m}{s^2}} + .0196\left(\frac{1.02\,m}{.0254}\right)\frac{(.13)^2\,\frac{m^2}{s^2}}{2 \cdot 9.8\,\frac{m}{s^2}}$$

$$\Sigma h_{lt} = .000431 + .000665$$

$$\Sigma h_{lt} = .00110\ m$$

$P_{2h} = 18665\ Pa \qquad P_{2L} = 1833\ Pa$

$$\frac{P_1}{\rho g} = \frac{P_2}{\rho g} + \frac{\bar{V}_2^2}{2g} + z_2 + \Sigma h_{lt}$$

$$\frac{P_1\,(1)m}{9800} = \frac{18665}{9800} + \frac{(.13)^2\,\frac{m^2}{s^2}}{(2)\,9.8\,\frac{m}{s^2}} + .75\,m + .00110\ m$$

$P_{1h} = 26034 \approx 195\ mm\ Hg$

$P_{1L} = 8702.23 \approx 65\ mm\ Hg$

Risk Assessment

Date	9/25/2008
Contributors	Alex Baxter

Summary	Likelihood (1-5)	Severity (1-5)	RPN Total
Number of 5's			84
Number of 4's	1	3	

#	Category / Tag	Risk	Description/Comment	Likelihood (1-5)	Severity (1-5)	Risk Priority Number	Mitigation Activity
1	Cost	Actuator Cost		2	3	6	6K budget.
2		Actuator crestes a negative pressure	Negative pressure created during retraction/filling	2	2	4	Control system or adding relief valve to system
3	Design	Water Column Inertia	During reversing water column will have inertia causing non-idealization	3	4	12	Build factor of safety and flexibility into system
4		Tank/Tubing Leak	Water leaks from the heart, tank, or tubing	2	3	6	Tight fittings, check to make sure all connections are sealed
5		Tank Pressue	Tank pressure does not meet the specs	1	3	3	Adjust the tank or water level to adjust the pressure
6	Materials	Actuator/Pump Innacuracies	Actuator does not pump water at the desired rate	2	2	4	Adjust the programming until the desired waveform is reached
7	Measuremer	Inaccurate measurements	Inaccuracy of measurements improperly placed flow meters	1	2	2	Place the sensors where they will record the desired measurements
8		Assembly error	Connections not tight, tubes not connected to the correct ports	1	3	3	Check all connections before turning on power and testing the simulator
9		Labview errors	Trouble communicating between computer and sensors, not reading desired values	2	3	6	Debug software to ensure desired results
10	Methods	Overload Actuator	Put to much pressure on the actuator	1	4	4	Review actuator data sheet to make sure we do not use inputs that are too large
11	People	Water Spill	Caused by user error, loose connections, incorrect filling or draining	1	2	2	User must be careful when filling the tank and assembling the tubing
12	Scheduling	Lead time for actuator	Actuator takea long time to receive	3	3	9	Specify and order by week 6
13		Losses in System cause inaccuracies	Viscous fluid losses non-idealization	4	4	16	Build factor of safety and flexibility into system
14	Simulations	air column resonance	Air may resonate during pulsation	1	2	2	Analyze system for resonance (Helmholtz resonance theory)