Blood Flow Experiment

Introduction

"Blood flow is defined as the quantity blood passing a given point in the circulation in a given period and is normally expressed in mL/min." [1] Given this definition, blood flow is related to blood pressure within living organisms. More specifically, this applies to the blood flow within the veins of living organisms. On average, the blood flow in the total circulation of an adult is about 500 mL/min. [1] This value is known as the cardiac output.

When thinking of this information in terms of how it applies to medical devices, it can be related to instruments such as stents. "A stent is a mesh 'tube' inserted into a natural passage/conduit in the body to prevent or counteract a disease-induced, localized flow constriction." [2] Generally, stents are applied when congenital heart disease is present. [3] Stents are also used to prevent vessel aneurysm "or to ensure the patency of existing or newly created intracardiac communications."[3]

It is important to understand how the cardiac system works in order to be able to implement the use of devices such as stents. Knowing what the desired range of values for blood pressure is helps to be able to treat patients with potential health issues and to even improve upon the devices that are used in treatment.

The methods used in this lab are a valid way to test for the linear flow velocity within a vessel. The information collected in this type of lab could be used to test for turbulent or laminar flow within a vessel. Laminar flow is defined as "uninterrupted flow in a fluid near a solid boundary in which the direction of flow at every point remains constant."[4] Turbulent flow is defined as "a fluid flow in which the velocity at a given point varies erratically in magnitude and direction."[5] Given these definitions, it's obvious that laminar flow is the desired flow when using a device such as a stent. The information used in this type of lab could be a way to analyze what type of flow is within a vessel and if the use of a stent is necessary.

Materials and Methods

For this lab, the pressure of citrated sheep blood and water in the Venturi Apparatus were measured at 1 mL/min and 10 mL/min each. The pressure of water was measured first at 1 mL/min.

In order to measure the pressure, the syringe was filled with water. The water in the syringe was then emptied into the Ventri Apparatus until the Venturi Apparatus was full and the syringe was placed in the syringe pump (model Kd scientific) with water still left inside the syringe. The Kd Scientific syringe pump was then set at 1 ml/ min. Once everything was in place, the Kd scientific syringe pump was turned on and the pressure was measured at each of the four positions using the Pasco PS-2164 Quad Pressure sensor. The data was collected for about three minutes at a sampling rate of 10 Hz using the Pasco SPARKvue software. This process was repeated for water at 10 mL/min, for blood at 1mL/min and for blood at 10 mL/min.

To plot the data that was collected by the SPARKvue software, MATLAB R2013b was used. The data files were converted into Microsoft Excel 2010 files. Those were then imported into MATLAB R2013b and used to plot the pressure vs. time for all of the data sets, calculate the linear flow of velocity at all of the pressure points, and then to plot Reynold's number vs. position for all four data sets.

To calculate the linear flow velocity, the equation used in MATLAB R2013b is given below.

$$Q = \rho * V * A \quad (1)$$

The equation used in MATLAB R2013b to calculate Reynolds number is given below.

$$Re = (\rho * V * L)/\mu \quad (2)$$

Results

The plots shown below are Pressure vs. Time at each of the four positions. All of the graphs shown below are color coded by position. For each one, position one is shown as red, position two as black, position three as green and position four as blue.

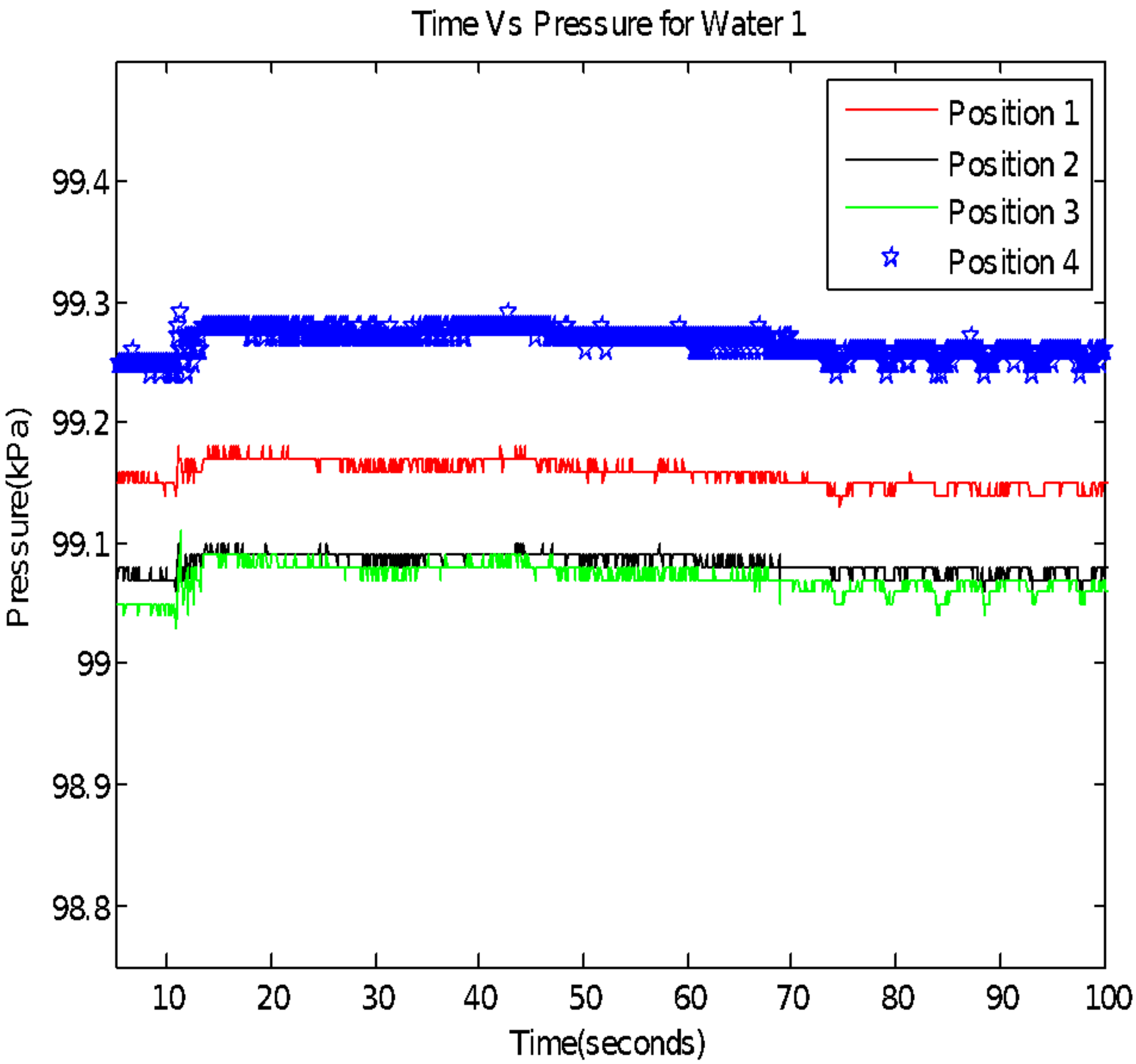

Figure 1. shows the time vs pressure at each of the four positions for the 1 ml/min blood trial.

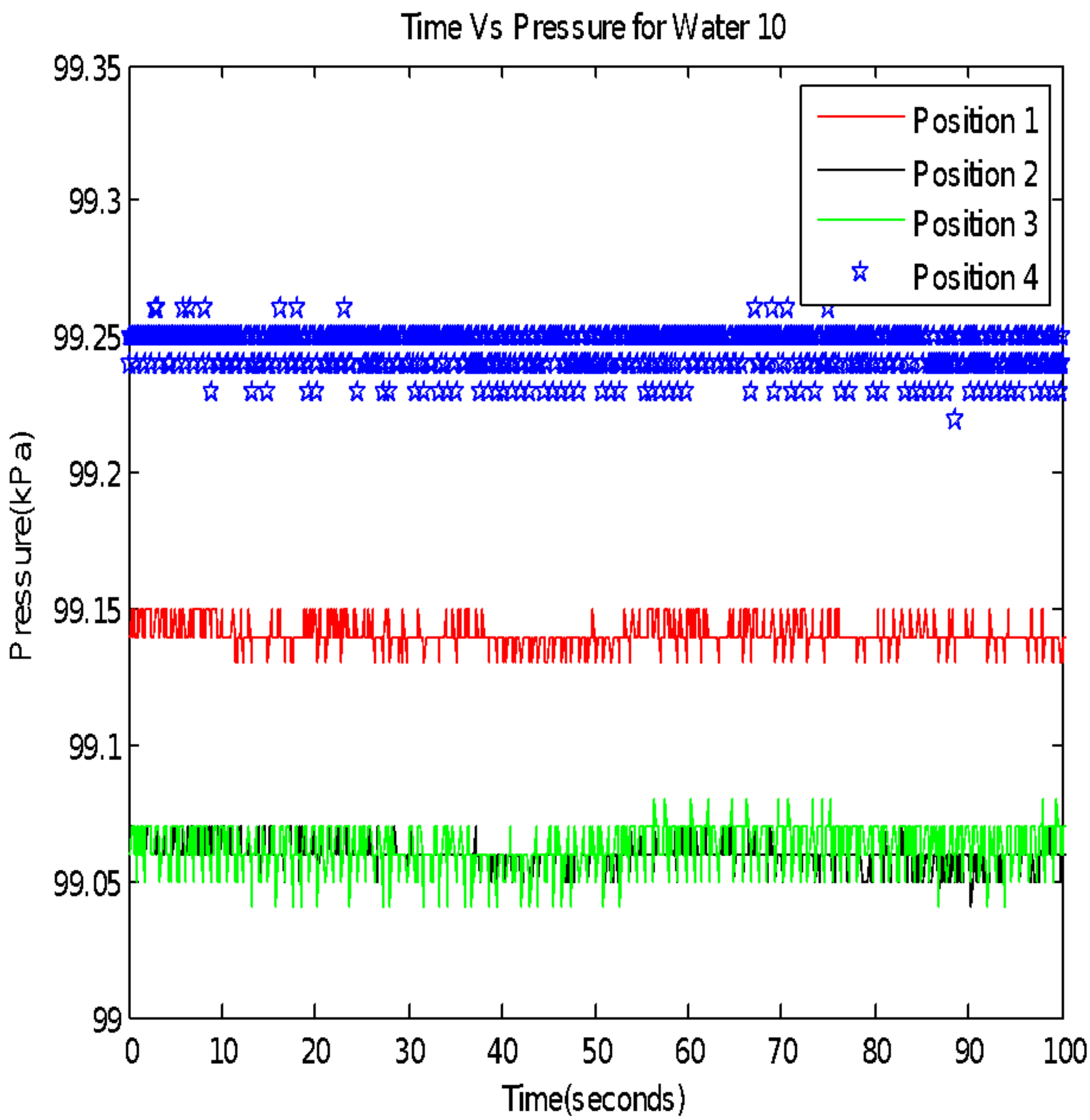

Figure 2. shows the time vs pressure for the 10 ml/min water trial at each of the four positions.

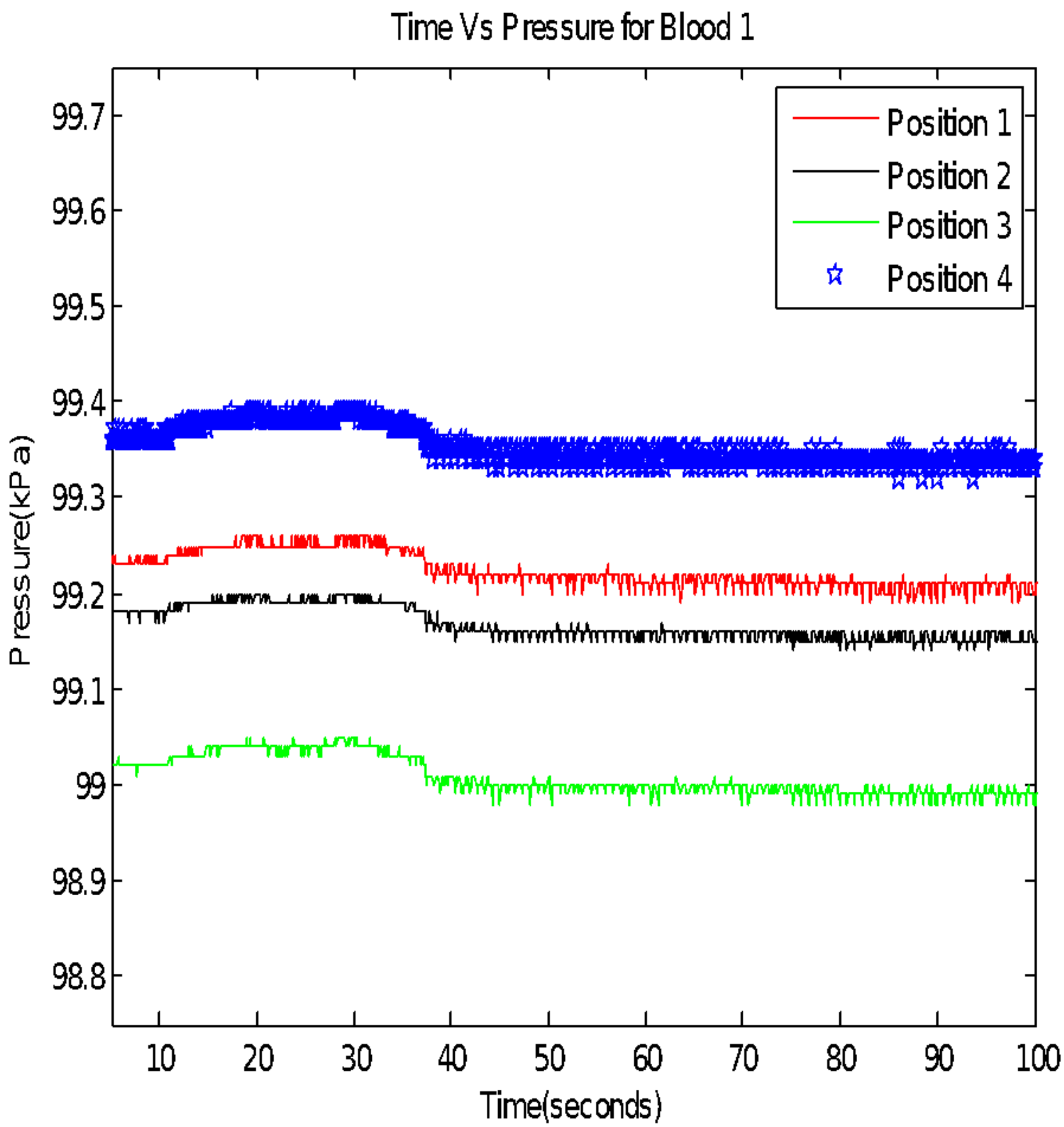

Figure 3 shows time vs pressure for the 1 ml/min water trial at each of the four positions.

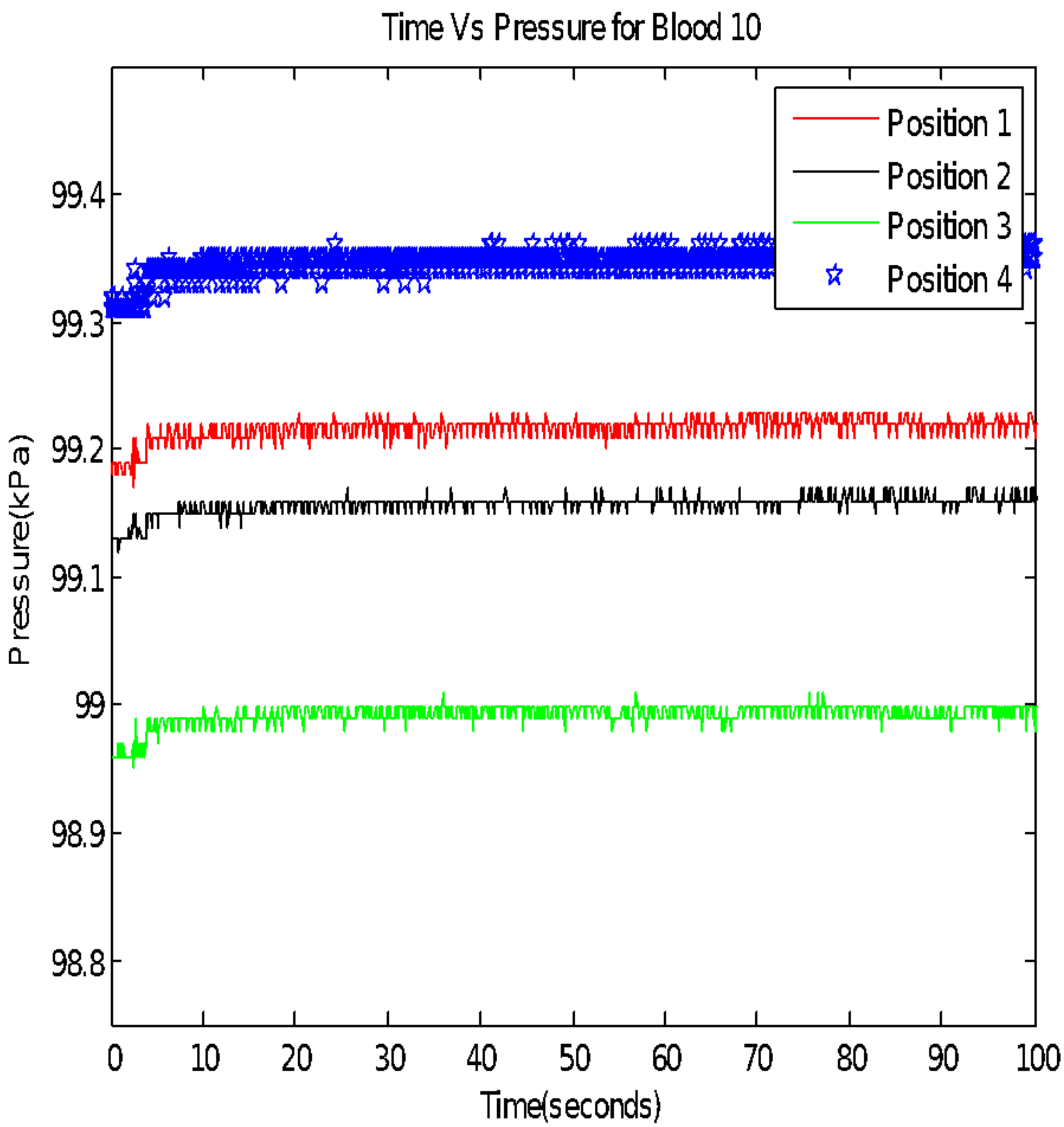

Figure 4 shows the time vs pressure at each of the four positions for the 10 ml/min water trial.

Table 1. Velocity Values in mm/s				
	Trial 1	Trial 2	Trial 3	Trial 4
Position 1	688.6208	688.4511	650.0512	649.9765
Position 2	4128.7	4127.3	3898.1	3897.6
Position 3	688.0509	687.9507	648.6248	648.5184
Position 4	4136.3	4135.1	3905.4	3905

Table 1 shows the calculated velocities of the blood and water at each of the positions. Trial 1 is water at 1 mL/ min, trial 2 is water at 10 mL/min, trial 3 is blood at 1 mL/min and trial 4 is blood at 10 mL/min.

Figures 5 and 6 shown below are the plots of Reynolds number, which was calculated using MATLAB R2013b, vs the position.

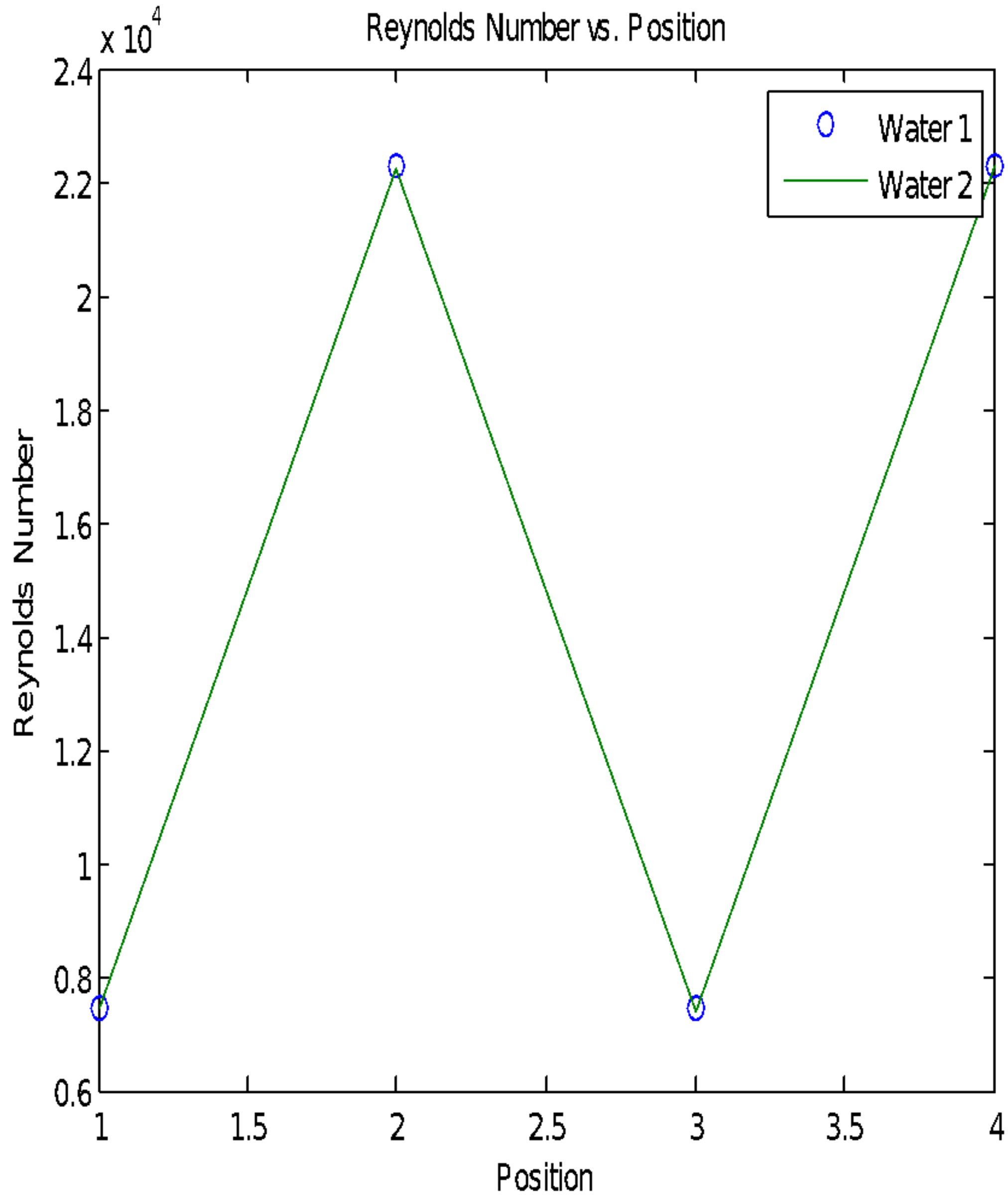

Figure 5 shows the calculated Reynolds Number vs the position for each of the water trials.

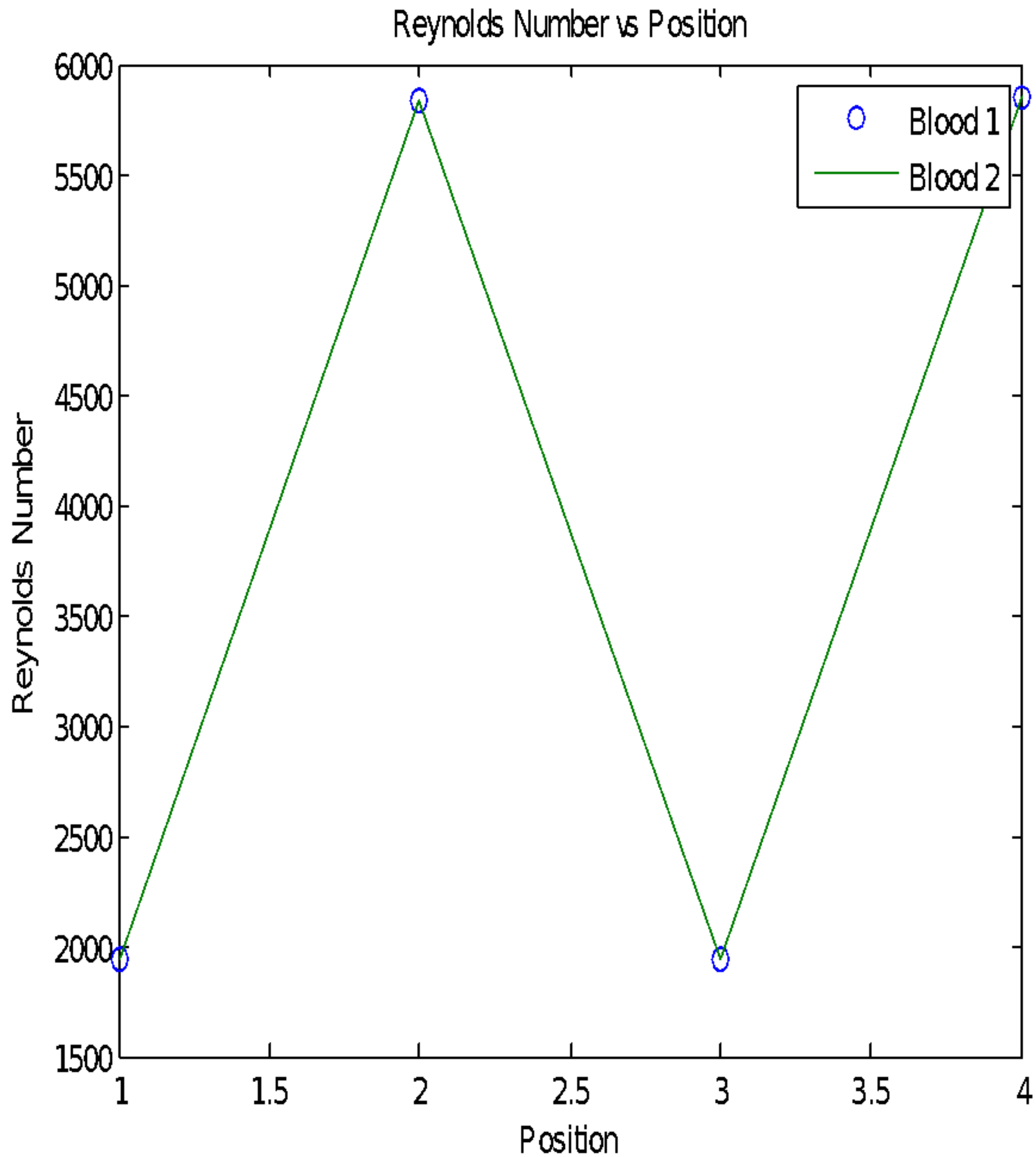

Figure 6 shows the calculated Reynolds Number vs. Position for both of the blood trials.

Discussion

Analyzing the data shown by the graphs above, it can be clearly seen that the flow rate does not have a profound affect the pressure observed. When comparing Figure 1 and Figure 2, there is a small difference in the pressure readings because of the difference in flow rate. In Figure 1 the flow rate was set at 1 mL/min and the pressure ranges from about 99 kPa to 99.3 kPa at the four positions. In Figure 2 the flow rate was set at 5.743 mL/min and the pressure ranges from about 99.05 kPa to 99.25 kPa. Similar results can be observed when comparing Figure 3 and Figure 4. This could be because there was not a significant enough difference in the flow rate values. The maximum flow rate was intended to be 10 mL/min, however the syringe pump only reached 5. 743 mL/min.

Positions one and three were placed at a width of about 24 mm in the Venturi Apparatus while positions two and four were placed at a width of about 4 mm. Figures 5 and 6 show the calculated Reynolds number versus the position in the Venturi Apparatus. When looking at Figure 5 and Figure 6 it can be seen that the Reynolds number is the same at the corresponding positions. For example, when looking at Figure 5 the calculated Reynolds number is the same at positions one and three and the same at positions two and four.

Using Figures 5 and 6 the type of flow can be determined. The conditions for laminar flow is that Reynolds number is less than 2000 and the conditions for turbulent flow is that the Reynolds number is higher than 3000 while anything in between these values is transitional. Using this information and the Reynolds values shown by Figures 5 and 6, the type of flow can be determined for blood and water. When analyzing Figure 5, it is shown that laminar flow is the dominant type of flow in the water trials. When analyzing Figure 6, it can be seen that at positions one and three the flow is transitional while at positions two and four the flow is turbulent.

These results could be attributed to the differences in the density and viscosity values for blood and water. Since blood has a higher density and a higher viscosity than water, the Reynolds values are higher and therefore produce turbulent flow at the narrower positions. The width of the Venturi Apparatus also contributes to the differences in the calculated Reynolds number.

This could be associated with the flow of blood within a vessel. The flow is more turbulent in a narrower environment. The use of stents could correct this type of flow. A stent could be placed in a narrow vessel in order to correct the turbulent flow within it and aid in the treatment of patients with illnesses like congenital heart disease.

Conclusion

In conclusion, the pressure was not greatly affected by the flow rate. There may have been a greater effect on pressure if the flow rate varied more. Also, if the syringe pump used had a higher maximum flow capacity then the testing may have been more accurate.

Both water trials had laminar flow while the blood trials had transitional flow for positions one and three and turbulent flow for positions two and four. This information could be applied to the flow of blood within vessels. It can be stated that turbulent flow is more prominent in a narrower space. The use of a stent could be to expand the vessel to decrease the amount of turbulent flow. This could aid in the treatment of diseases like congenital heart disease.

References

1. Levins, Kirk. "Relationship between Blood Flow, Vascular Resistance and Blood Pressure." N.p., n.d. Web. 29 Nov. 2014.
2. "Stent." *Wikipedia*. Wikimedia Foundation, n.d. Web. 29 Nov. 2014.
3. Peters, Bjoern, Peter Ewert, and Felix Berger. "The Role of Stents in the Treatment of Congenital Heart Disease: Current Status and Future Perspectives." *National Center for Biotechnology Information*. U.S. National Library of Medicine, 29 June 2005. Web. 29 Nov. 2014.
4. "Laminar Flow." *Merriam-Webster*. Merriam-Webster, n.d. Web. 29 Nov. 2014.
5. "Turbulent Flow." *Merriam-Webster*. Merriam-Webster, n.d. Web. 29 Nov. 2014.