Project report: Control and instrumentation for organ transplant circulation machine

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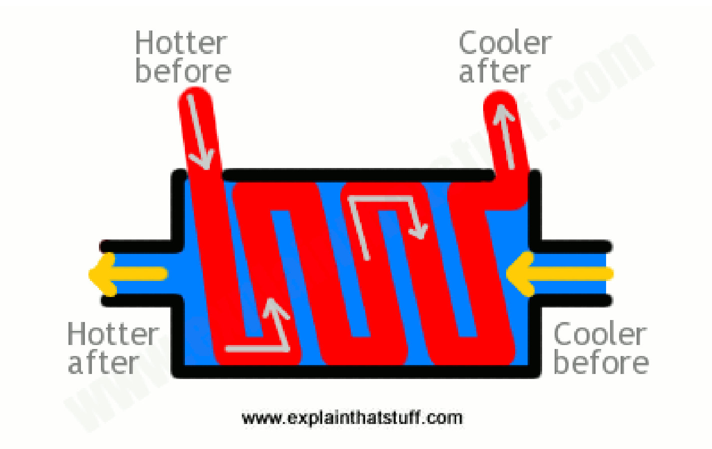
My project was in association with the local hospital working on a system which pumps blood around the body of an organ donor so that when these are transplanted into someone in need of these organs the operation is more likely to be successful. Studies around the world have shown this technique to be very successful and greatly increase chances of survival. To do this the temperature of the blood must be controlled as well as the speed and pressure at which the blood flows around. Throughout my experimentation I used water in place of blood.

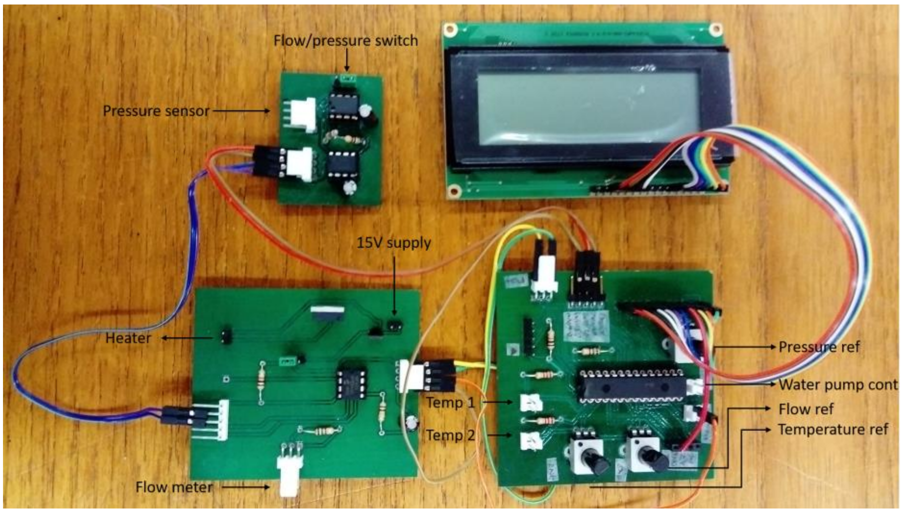
Temperature

In many systems already in place the temperature is controlled by using a **heat exchanger.** This has two tubes with the water you wish to heat flowing in one direction and hot water you are using to heat it up flowing in the other, as can be seen. This allows you to heat up the water without actually having any contact with it, as with blood this could cause contamination. In my design I am trying to replace the water, used to heat, with air. This allows the system to be much more transportable as the air can be drawn from the surroundings, you do not have to carry loads of water with you. Since air transfers heat a lot less effectively you need a lot more of it. A large pump was therefore required to pump it round fast enough. The temperature of the air was then controlled by passing it through a heater. This is just a large amount of wire wound in lots of loops with a high current passed through it. The high current causes the wire to get very hot and, when the air is pumped through it, this heat is transferred to the air. This temperature can then be controlled by controlling the voltage supplied to it. Tests were also performed with many different heat exchangers to see which would be the most suitable.

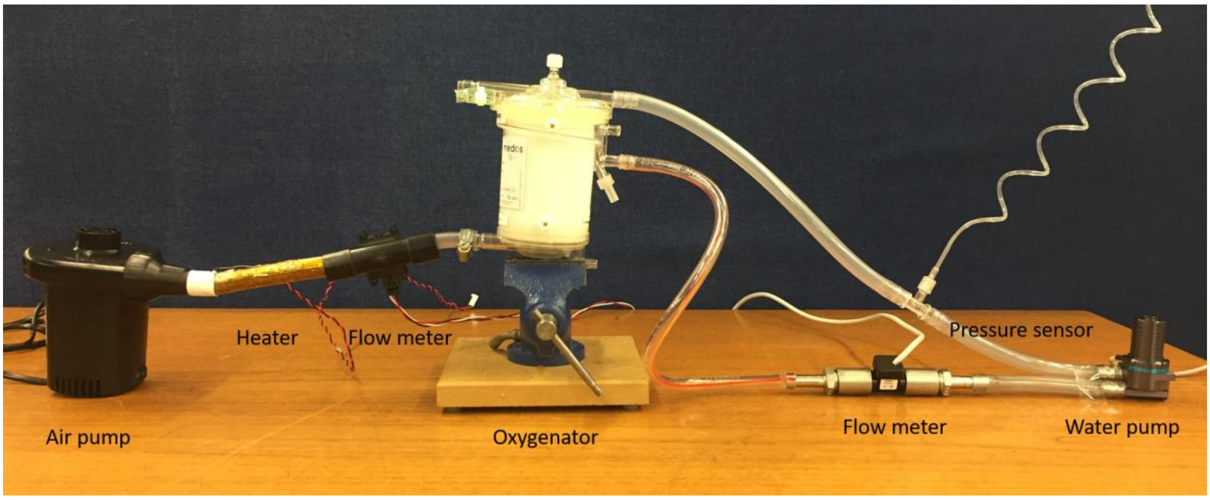


Flow

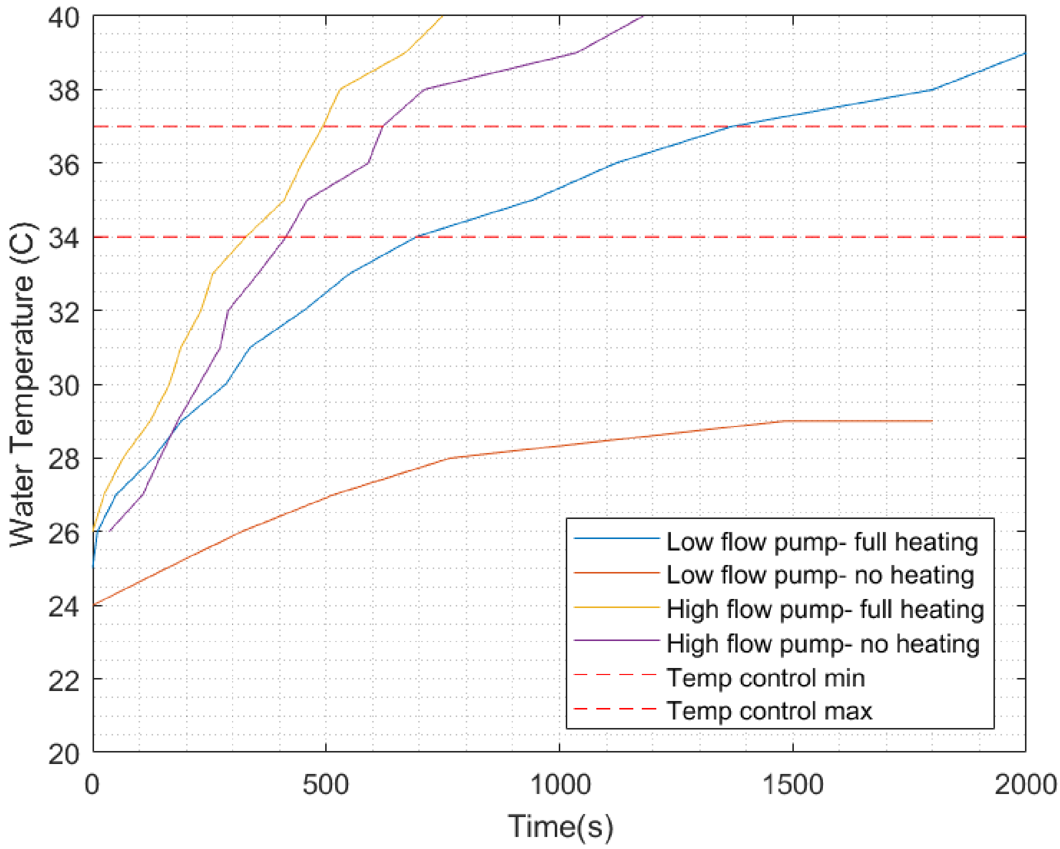
There are two aspects of flow which need to be controlled in this system. One is the **flowrate**, so essentially the speed the water flows at, and the other is the **pressure,** similar to the force the water applies on the tubes surrounding it, as it flows through them. Since one has an effect on the other they cannot be controlled separately, however in this design the user can select which of the two they wish to control. There are therefore sensors to measure each, placed in the system. Each of these sensors give a different signal, for example the flow sensor gives out pulses of signal, the frequency of which is related to the flowrate, while the pressure sensors give out a voltage which changes with pressure. All of these signals are put into a microcontroller which I have written code in to convert all of these back into actual measures of pressure and flow rate (the same was also done for electrical temperature sensors). To change the pressure and water flow an output signal is supplied to the pump which is pumping the water around the circuit. This will change the speed of it accordingly. The **control system** therefore works such that the user will put in (using some dials) what pressure or flow they want, and the system will either increase or decrease the speed of the motor pumping the water round until the output from the sensor matched the selected value. This has to be carefully tuned since if you were to change it too quickly you would always go too far, since the sensors do not respond immediately, however too slow and it would take far too long to reach the correct value. The majority of this is all written in the code however a lot of the sensors require hardware to set them up. I therefore designed circuit boards, as can be seen, to get this all to work. These are all connected to a screen to display the required information.



Testing the system



Once the system was all set up, as seen above, with all the sensors and control working, I was then able to investigate whether using air would actually heat the blood up to a sufficient temperature. Many tests were run to determine this. One example is to look at the changing temperature of the water when using an air pump and heater, with the water flowing round the circuit. The results can be seen below.



As can be seen two different pumps were tested. For each pump the system was left running and the temperature measured once with the heater set to permanently on, and once with the heater off. The two red lines show the temperatures we wish to control between. With the low flow pump you can see that, by varying the input to the heater, it would be possible to control the temperature at any desired point between approximately 29°C and 39°C. However for the high flow pump, even with the heater completely off the temperature gets too high. This is because the pump itself heats the air up too much, it could therefore be concluded that this particular pump would not be suitable.

Conclusion of work

By the end of the project the system was set up with the electronics and code working well and sufficiently controlling the pump speeds and heater. However further investigation was required, using this set up, to determine exactly what kind of pump would be required to pump the air round at the right speed and temperature to heat the blood as we would like.