Monitoring Environmental Chamber Efficiency Using a Raspberry Pi

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Abstract

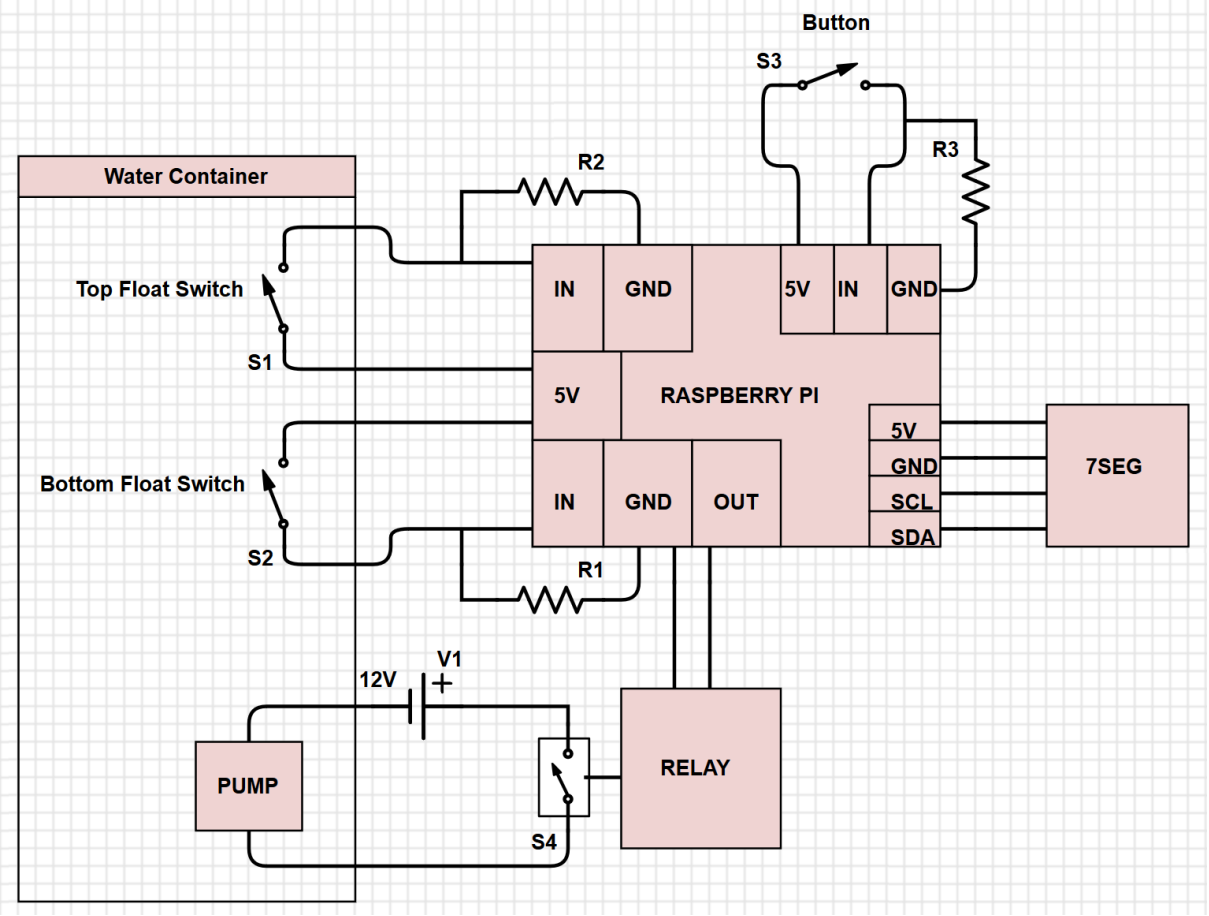
An environmental chamber in the ATLAS laboratory at OSU, which is responsible for testing many technical components sent to the LHC, began leaking water. In order to determine if this was affecting the conditions inside the chamber (and thus comprehensively testing the components), I designed a pumping system to measure the rate of leakage and compared it to the amount of humidity needed inside the chamber. I determined that the chamber may not be replacing the water vapor at a sufficient rate.

Introduction

Ohio State's ATLAS[1] division specializes in the design and production of fiber-optic transceiver boards (opto-boards). To ensure that the opto-boards can survive five years of use, thirty-two opto-boards (out of a total of 400) are subjected to an 85-85 test, where they are placed in an environmental chamber of 85 degrees Celsius and 85 percent relative humidity. For the materials used in constructing an opto-board, the chemical reaction rate doubles for approximately every 6 degrees Celsius of temperature.[2] Therefore, a test at 85 degrees Celsius (62 degrees above room temperature) will test the opto-board's resistance to humidity and simulate its material degradation at a rate of 2 to the power of 62/6 — approximately 1,290 — times faster than the normal rate at room temperature.

Unfortunately, the imperfect lining around the seams of the environmental chamber allows some of the water vapor to escape in the form of condensation. This poses two risks. One risk is that the lack of sufficient water vapor in the chamber will mean that the resistance of the opto-boards to humidity has not been sufficiently tested. The other risk is that the water may saturate the insulating lining and cause it to lose its insulating ability, allowing heat to escape the chamber.

Methods



Excess Water Management

The condensed water was directed out of the environmental chamber and into a container with two water level switches and a pump. The water will begin draining every time it reaches the top switch and will be pumped out until it reaches the bottom switch. There is also a manual pump button and a 7-segment display indicating the amount of time since the water was last drained. The Raspberry Pi keeps track of how often the water is pumped out.

Methods

Data Analysis

By monitoring how often the container is drained, I could calculate the rate of water leaking from the environmental chamber. Then, using the formula for saturated vapor density as a function of temperature, I could determine how much water was supposed to be in the chamber at any given time.[3] Using these results, I calculated the percentage of the water vapor intended for the chamber under 85-85 conditions that was escaping the chamber per hour.

% of water mass escaping:

$$\frac{\text{(average \# of containers drained per hour) x (volume of container) x (water density at room temperature)}}{\text{(volume of chamber) x (vapor density at 85°C) x .85}}$$

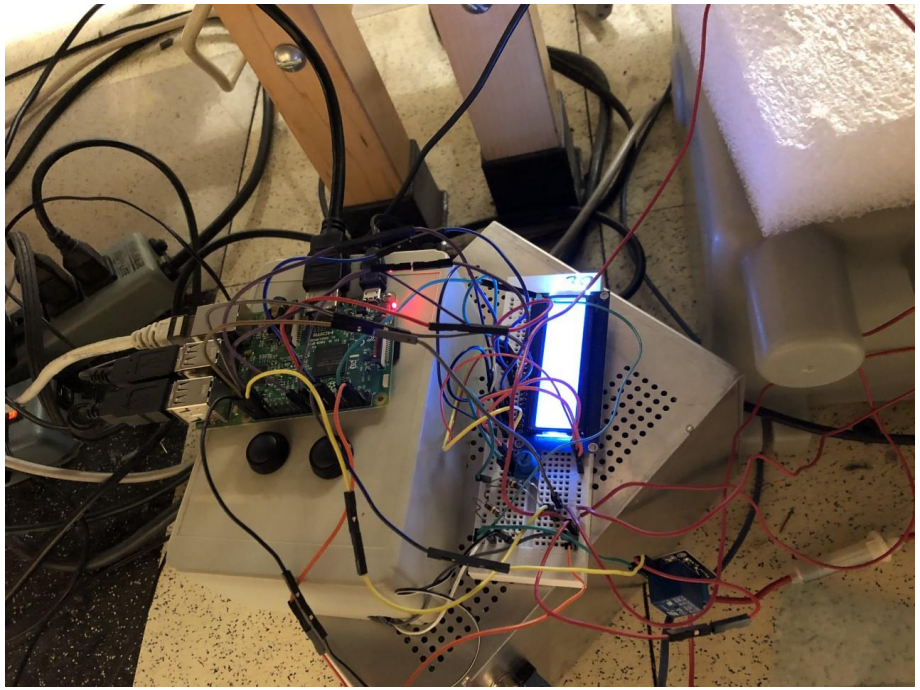
Vapor Density formula:

$$VD = 6.335 + .6718*T - .020887*T^2 + .00073095*T^3$$

Results

Excess Water Management

My design was successful at pumping all the excess leaking water, maintaining the safety and cleanliness of the lab environment.



Data Analysis

Although the rate at which the water was pumped out was not always consistent, the % of water mass leaking per hour was always multiple orders of magnitude larger than 100%. This means that the environmental chamber is constantly working to replace lost water vapor, so we can’t be certain that it is always at 85% humidity.

Conclusions

This experiment shows that it is uncertain whether the environmental chamber is operating at 85% humidity. Thus, simply pumping the water out is an insufficient solution and the damaged chamber must be either repaired or replaced.

If the results had shown that the leaking water was an insignificant fraction of the water in the chamber, then this project would have been sufficient, and a costly solution could have been avoided, but unfortunately that is not the case.

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References

1. The ATLAS Experiment. https://atlas.cern/discover/about

2. Arrhenius equation. https://www.britannica.com/science/Arrhenius-equation.

3. Relative Humidity. http://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/relhum.html#c3