Volume Measurement

Overview

BrewTroller can use any 0-5V DC analog device to represent the current volume of a vessel. A set of calibrations for the vessel must be recorded to map specific signal values to known volumes. There are ten calibration values that can be created per vessel. BrewTroller will use the map to plot values between calibration points.

The most common method used for measuring volume with BrewTroller is using pressure sensors. As the height of the liquid increases in a vessel the pressure increases in a corresponding way. Measurement for initial filling can be quite accurate but as temperature decreases volumes will drift as a result of a small vacuum created by the air in the pick up tube connected to the pressure sensor. BrewTroller users cleverly discovered that using a small air pump and feeding a constant stream of air into the pick up tube would eliminate this vacuum and result in accurate volume readings across temperature changes.

Bubbler Theory

A small air pump is used to force air (at a very low flow rate) into the pressure sensing tube. This forces air to bubble steadily out the end of the pickup tube. The pump runs at all times during use. By ensuring that the tubing is always completely full of air, the pressure reading is always consistent - most importantly, it does not vary with temperature, which is a non-trivial issue in a sealed-tube arrangement.

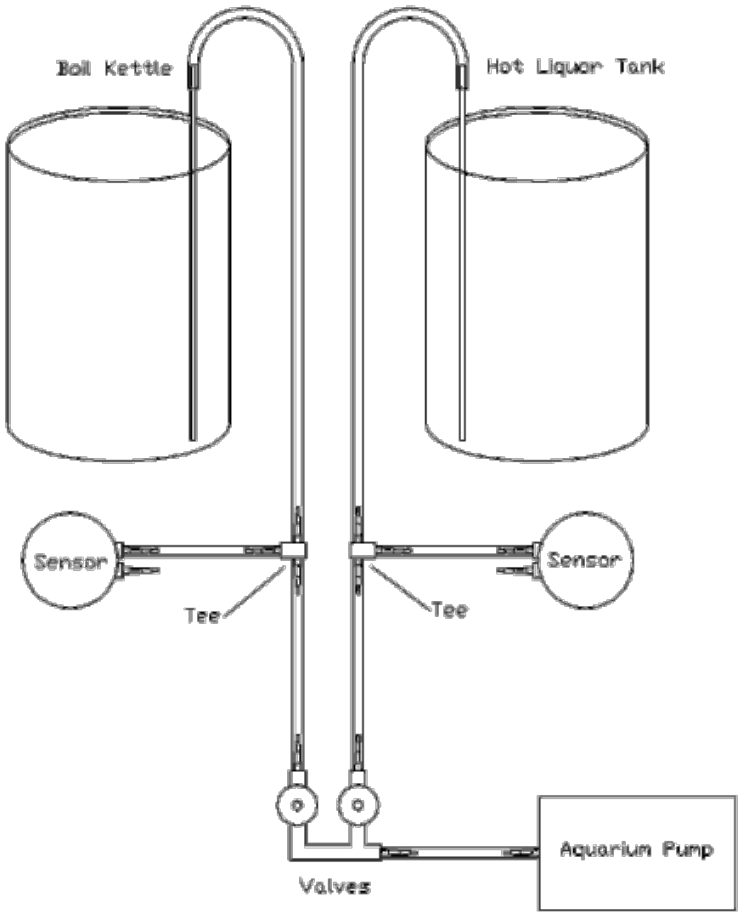
By its very nature, this arrangement is also immune to minor air leaks, and can recover from a temporary disconnection of the air line tubing (accidental or otherwise) during use, either of which are catastrophic in a sealed-tube setup.

There is also no significant risk of moisture/steam reaching the pressure sensor itself, due to the constant stream of air purging the tube.

One caveat of this setup is that the continuous formation and release of bubbles at the end of the pickup tube does introduce a steady ripple in the pressure sensor reading. Appropriate averaging in the BrewTroller, and/or hardware filtering, can reduce this significantly.

Hardware

In addition to the pressure sensors, air line, and dip tube needed for the standard sealed-tube arrangement, this method requires the addition of tee fittings, air flow valves, and a pump.



All of these additional parts are available in the aquarium sections of typical pet shops - it should cost less than $15 for parts sufficient for 1-4 sensors.
A "gang valve" allows one pump to supply many sensors, with an air adjustment valve for each. Even the smallest aquarium air pump should suffice for this application.

Setup

As with any pressure sensor arrangement, the dip tube end should be placed as deep in the vessel as possible (to cover the widest range) and must be fixed in place, as any movement can throw off the reading.

Air flow should be adjusted to achieve a rate of about 2-3 bubbles per second. The rate of bubbles will vary with water depth, so during adjustment the vessel should ideally be at least half full.

Performance Enhancement

The ripple present in the pressure sensor reading due to the bubbles formed with this arrangement shows up as noise in the reading. This noise typically corresponds to a variation of less than a quart; however, the BrewTroller firmware includes averaging on the volume sensors to reduce or eliminate this noise. If necessary you can fine tune the averaging logic in the Config.h of the BrewTroller

Technical Validation

Test 1: Volume reading sensitivity to temperature changes

The following test was conducted:
- Fill vessel slowly with cold tap water
- Allow it to rest, verifying that the volume reading is stable
- Heat to boiling, verifying that the volume does not change unexpectedly during the process
- Boil for a while, watching the reading decrease due to boil-off

- Cool back to near room temperature (alternating between slow and rapid cooling), verifying that the volume reading is stable throughout

Note: This test was conducted using the standard BrewTroller 1.2 firmware, which averages 5 samples taken 200ms apart. The ripple seen in the reading is due to the bubbling at the end of the pickup tube. This ripple can be all but eliminated with a combination of more robust averaging and/or minor hardware modification.

Test 2: Volume reading stability

Note: This test was conducted with hardware and code changes.

Link to test results
This test gives an indication of how stable the volume reading can be when set up appropriately. This data showed a variation of +/- 0.01 gallon in the reading with a constant liquid level. It also serves as a small example of the repeatability, as some water was removed and re-added.

Test 3: Interaction between multiple sensors on a single pump

Note: This test was conducted with hardware and code changes.
A concern was expressed regarding the interaction between the volume readings of multiple vessels when running from a common air pump.

This test involved leaving a constant volume of water in one vessel, and varying the level of water in the second vessel from completely empty to completely full, and then draining again.
The hardware configuration was just like that in the diagram above: one pump feeding a gang valve, feeding two separate sensor pickup tubes in different vessels.
A shift of no more than 0.01 gallon was observed, demonstrating that this is a non-issue when set up as recommended above.