Rainwater Isotopic Sampler Checkvalve
Designed and Printed at the OPEnS Lab
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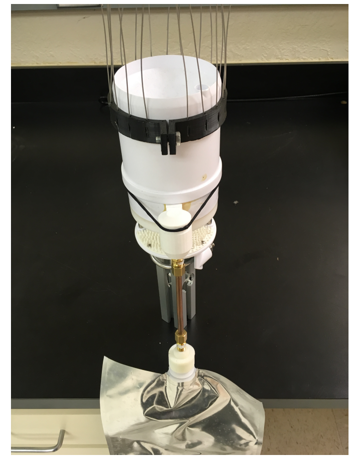
Summary

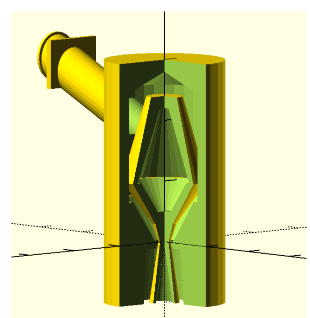
A one-way valve that allows water through-flow but limits water-vapor outflow was designed and 3d printed to be connected to the water outflow of a TAHMO weather station [1]. The valve prints as one piece with removable supports to separate into two pieces: the outer shell and the inner "buoy". The buoy is normally seated in a socket, blocking outflow, and rises as the buoyant force increases as water flows into the valve. The bottom of the valve is meant to be tapped in order to be fitted with a 1/8" NPT tube fitting for a copper tube to direct water into an aluminum lined collection bag.



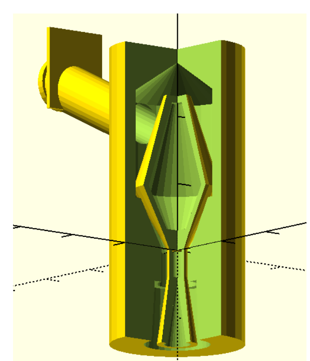
TAHMO station with a valve (white) connected via ziptie. An aluminum-lined bag is below the valve, and a copper tube joins the two.

Background

One useful measurement performed on collected rainwater globally is the ratio of hydrogen and oxygen isotopes, used for various meteorological and climatological studies. Lighter isotopologues of water evaporate at faster rates than heavier ones, so limiting evaporation of these samples is necessary. Various methodologies for capturing rainwater have been in use for decades, though they are either costly, poorly limit evaporation, or have other problems [2]. This valve was designed to address the faults of other methods while remaining cheap and accessible to researchers.



Version 1 (corner cut for visualization)



Version 4

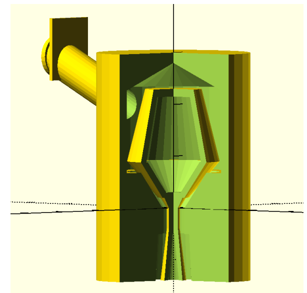
Design Iterations

The design was based off of a one-way valve posted on Thingiverse [3] that utilized a copper pellet. This was recreated to fit to the TAHMO Station's outflow lip and to allow a 1/8 NPT fitting to screw into the output of the valve, allowing a copper tube to connect the valve to an aluminum bag for storing the collected water.

All designs were made in OpenSCAD, an open source CAD software that is free and available globally with a minimal learning curve so that researchers who wanted to modify the design could do so easily.

The first design (*Version 1*) featured a standing buoy inside the body of the valve. The inner chamber's inlet was a leg sticking out of the body that would slide into a socket in the TAHMO station's outlet. The outlet of the inner chamber did not account for the 1/8 NPT fitting at this stage.

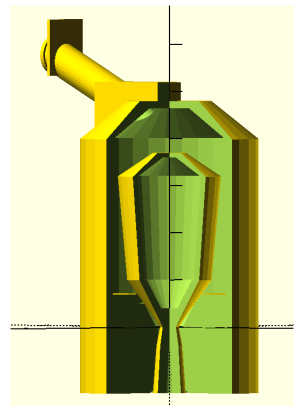
Some problems with this design included the poor printability of the valve and the lack of enough space in the inner chamber to provide the buoyant force needed to lift the buoy.



Version 6

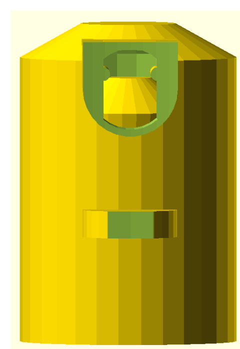
The printability of the valve was the main issue addressed over the next few iterations. In version 4.2, the valve's spigot connection to the lip of the TAHMO station was modified to provide a better fit, and among other changes the valve's shape was elongated to reduce the angles of the walls slightly and to allow more space and to improve printability.

By version 6, more space was made in the inner chamber by increasing the diameter of the valve, and the buoy's diameter was increased with it. This was an effort to allow the buoy to displace more water and cause a greater buoyant force. Previous designs' buoys failed to reliably lift from the socket when water entered the chamber.



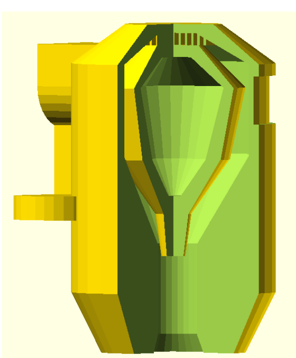
Version 10

Between versions 6 and 10, the buoy was changed several times for both printability and functionality purposes. The overall volume of the buoy was increased, the support stand was modified to allow easier snapping and more stable support, and the spigot was reinforced in the event



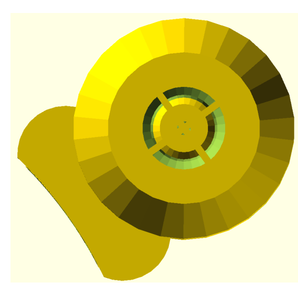
Version 11

Version 11 replaced the spigot connection with a rounded mouth. The opposite half of the valve's body was indented to allow a zip tie to press the valve to the catchment device to keep it in place. A foot was added below the mouth to stabilize the valve. The support stand was attached to the valve body by a thin removable cross at the bottom to further prevent movement of the support and buoy during printing.



Version 13. The indent for the ziptie can be seen on the top right side, and the new supports can be seen at the top of the buoy.

Version 13 was made with a larger foot and a support was added between the foot and mouth extensions to address shear forces on the foot. The unreliable support stand for the buoy was obsolesced by printing the buoy upside down, adding thin line supports to the top, designed to snap off with pressure from a flathead screwdriver.



Bottom view of version 11

Challenges in the Design Process

The primary challenge of the design process was printing the valve reliably. The valve needed to be printed in ABS thermoplastic to limit the environmental wear over time, though ABS is significantly more difficult to print with than other filament alternatives, including PLA. This is because, despite having a glass transition temperature of 105 degrees C, ABS doesn't have a specific melting point. To achieve the desired viscosity to print, the plastic is extruded at 230 C. Because of the amorphous nature of ABS, the extruded plastic doesn't immediately solidify and has time to warp, string, and flow before cooling down.

This is problematic for 3D printing the valve, which requires minimal deformation of the buoy and socket in order for the two to sit properly. As a result, the majority of the time spent on design was trial and error of slicer software settings and minor gradual changes to the shape of the piece. Future designs could address this further by printing the valve in two parts, allowing an O-ring to be incorporated into the socket as well as more thorough post-processing to smooth the valve socket and lower buoy.

Post Processing and Setup

Vapor-finishing [4] the printed valve with acetone will smooth out defects and further seal the layers together, and is recommended to be done before any other post processing.

There are several post processing modifications to the valve that need to be done before it can be used with the TAHMO station. In designs with a support stand, the first step would be to snap the buoy support stand off and remove with pliers. Current designs instead require a screwdriver to be pressed through the valve's mouth and into the support lines connecting the top of the buoy to the top of the valve's body. Breaking these support lines will release the buoy and allow it to move freely inside the valve's inner chamber as a separate part. The next step is to tap the opening at the bottom of the valve with a 1/8'' NPT tapered tap. After doing so, the bottom of the buoy should connect to a 1/8'' NPT tube fitting by screwing the two together. The mouth of the buoy fits snug onto the outflow lip of the TAHMO station and while pressing the two together, a long ziptie (or two combined together) should be wrapped around the station and the valve and tightened so that the ziptie sits in the valve's indent and presses the valve to the station firmly.

Conclusion

The valve is an excellent example of the limitations of fused deposition molding 3D printing. The parts were too small to print reliably on low- to medium-budget machines without the functionality being compromised due to warping or defects. It's clear that post processing of some form is absolutely necessary for this part and different methods should be explored. This valve could offer a great, cheap solution to limiting collected rainwater evaporation if print warping is overcome.

References

[1] TAHMO Project http://tahmo.org/

[2] IAEA/GNIP precipitation sampling guide, v2.02, September 2014. http://www-naweb.iaea.org/napc/ih/documents/other/gnip_manual_v2.02_en_hq.pdf

[3] Link to thingiverse file: http://www.thingiverse.com/thing:744215

[4] Kraft, Caleb, Makezine "Smoothing Out Your 3D Prints With Acetone Vapor", September 24 2014. http://makezine.com/2014/09/24/smoothing-out-your-3d-prints-with-acetone-vapor/