# Construction of a Low-Cost Diffusion Dryer for Aerosol Research

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**Introduction**

The diffusion dryer is a component commonly used in aerosol research to remove water vapor present in an aerosol. This type of dryer is desirable because unlike a direct desiccant dryer, a diffusion dryer can dehumidify aerosol without losing particles to the impact of the particle and the desiccant directly. The particles present in the aerosol are dried by the diffusion of water vapor from the aerosol to the desiccant, rather than from direct impact of the water vapor and desiccant, minimizing particle loss.

Commercial diffusion dryers typically cost over $3500. The price of commercial dryers present a need for a lower cost, research grade diffusion dryer. The total cost of the dryer constructed in this project was approximately $180, which is about 20 times cheaper than the leading commercial instrument. This diffusion dryer was fabricated with custom 3-D printed sealing caps and silicone rings to provide a high quality seal. Additionally, the transparent body of the dryer offers easy viewing of the desiccant status.

**Files**

- Half_Inch_Diffusion_Dryer_V5.SLDPRT : Solidworks design of sealing end caps
- Half_Inch_Diffusion_Dryer_V5.STL : .stl file of sealing end caps
- Diffusion_Dryer_BOM.xlsx : Itemized bill of materials

**Materials (McMaster-Carr Part #)**

- High-Temperature Soft Silicone O-Ring (1173N216)
- Square Profile High-Temperature Silicone Ring ⅛ Fractional Width (1182N223)
- Brass Hex Nut, 1/4"-20 Thread Size (92676A029)
- High-Strength Steel Threaded Rod, 1/4"-20 Thread Size, 2 Feet Long (90322A657)
- Indicating Bulk Silica Gel Desiccant for 23025 Cubic Inches (2181K93)
- Corrosion-Resistant Compression Spring Stock, 20" Long, 0.5" OD, 0.418" ID (9663K79)
- High-Temperature Expandable Sleeving, Stainless Steel, 3/8" ID (1478T2)
- McMaster Carr Clear Cast Acrylic Tube, 2" OD x 1-1/2" ID, 1 Foot Long (8486K535)
- PLA 3D Printed Diffusion Dryer Cap, *File Name:* “Half_Inch_Diffusion_Dryer_V5”
- Worm-Drive Clamps for Firm Hose and Tube, Steel Screw, 5/16" Wide Band, 7/16" to 25/32" Clamp ID (5388K16)

A more detailed description of the diffusion dryer cost and an itemized list of materials can be found under “Diffusion_Dryer_BOM.xlsx”.

**Methods**

Solidworks was used to design caps that would seal the 2 ends of the acrylic tube that would be used for the body of the diffusion dryer. After many iterations, the “Half_Inch_Diffusion_Dryer_V5” Solidworks file was 3D printed in PLA. The Solidworks part is shown in Figure 1 and the printed part is seen below in Figure 2.

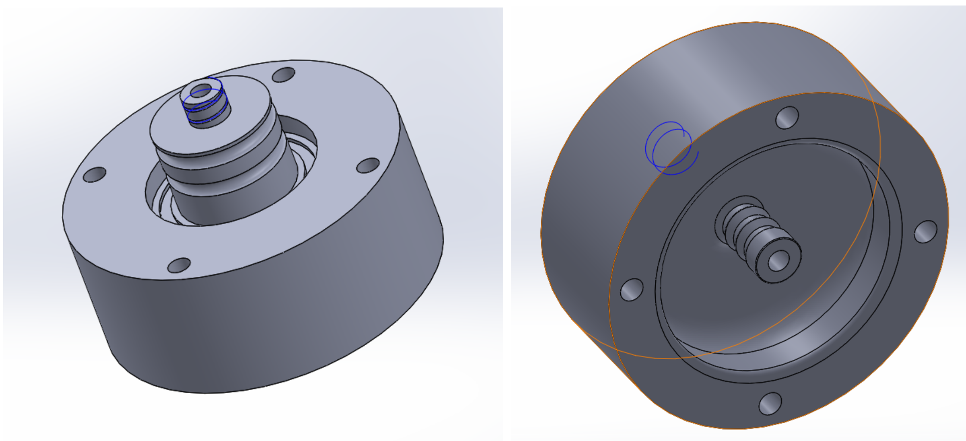

**Figure 1:** Solidworks design of the diffusion dryer cap.

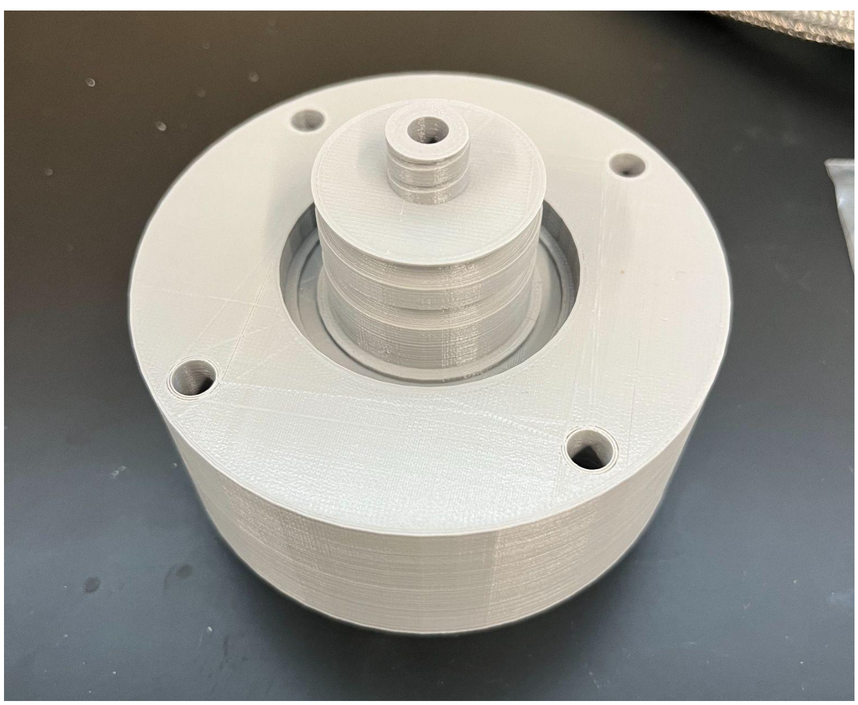

**Figure 2:** PLA Printed “Half_Inch_Diffusion_Dryer_V5”.

The part was designed with 2 notches for the circular profile silicone rings and 1 notch for the square profile silicone rings. The bottom has a ½” diameter barb for a ½” tube connection. The top protrusion of the part has a helical sweep cut for the connection to the spring (Figure 3).

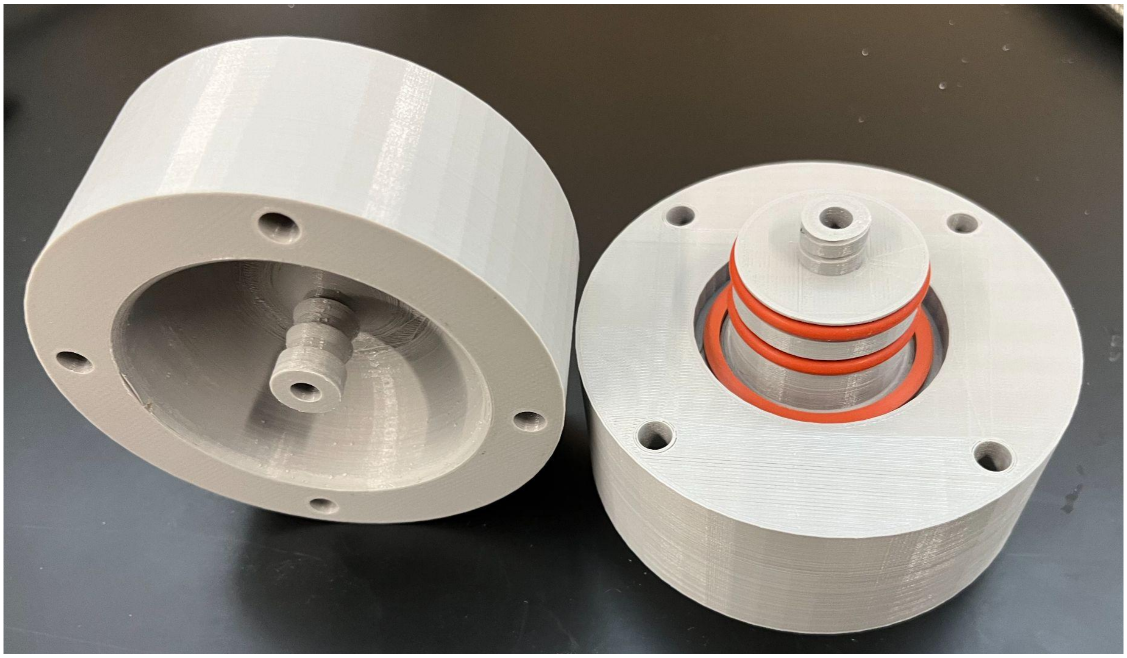

**Figure 3:** Diffusion dryer cap with the silicone sealing rings.

The expandable sleeving was then compressed to have higher porosity and diameter, and was fit around the spring. The spring was then connected to one of the diffusion dryer caps (Figure 4).

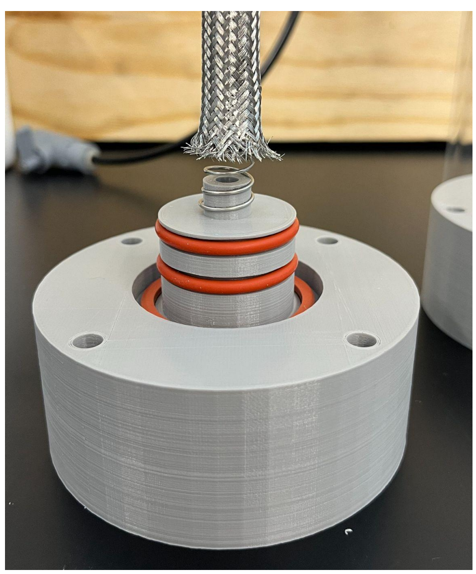

**Figure 4:** Spring and sleeving connected to one cap.

In order to fix the sleeving to the cap, a worm-drive clamp was used around the protrusion of the spring attachment so that no desiccant would accidentally enter the hole where the aerosol is traveling (Figure 5).

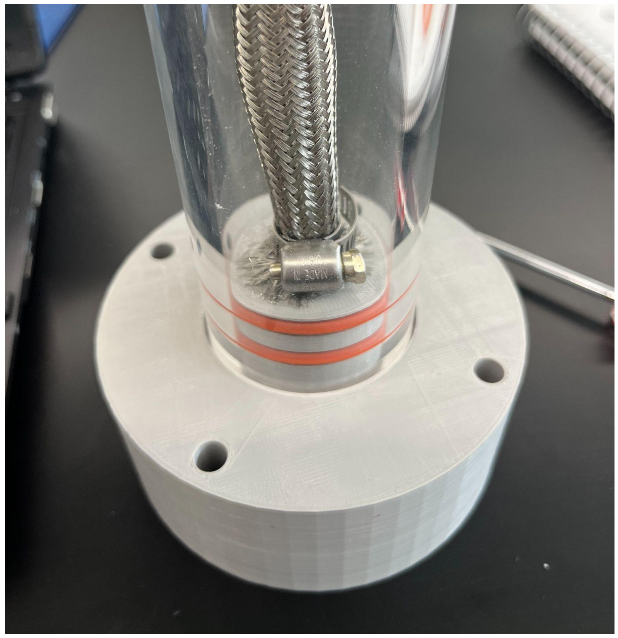

**Figure 5:** One diffusion dryer cap with a worm-drive clamp to fix the expandable sleeving in place.

Once one of the diffusion dryer caps was in place, the other cap was attached to the spring (Figure 6). A worm-drive clamp was attached around the sleeving and the desiccant was loaded into the acrylic tube. (Make sure all silicone rings are on the second cap before doing this).


**Figure 6:** Second diffusion dryer cap attached to the spring before the desiccant was loaded. Once the desired amount of desiccant was loaded into the acrylic tube, the second diffusion dryer cap was placed in the other end of the acrylic tube to seal the diffusion dryer (Figure 7).

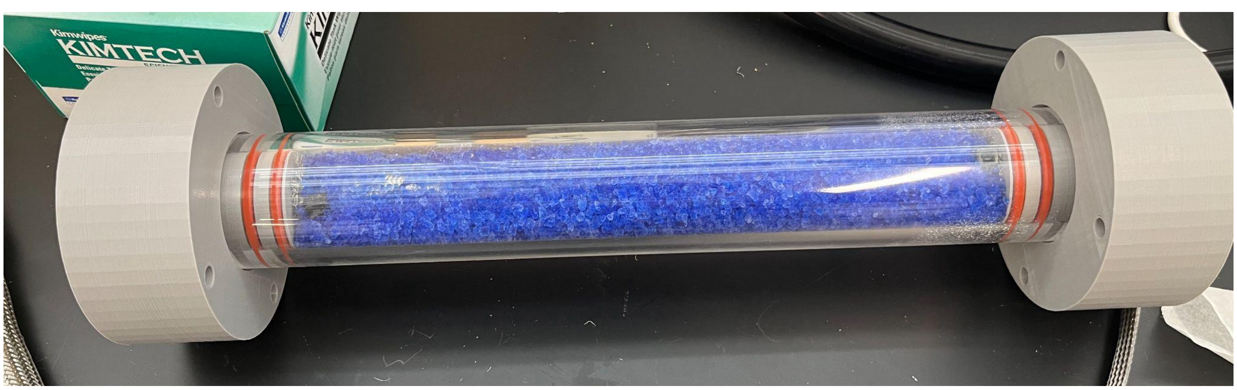


**Figure 7:** Diffusion dryer with the desiccant and both ends sealed with caps.

Once the caps were sealed on both ends, a ½" hose was connected to both barbs to create a closed loop to prevent the desiccant from absorbing humidity from the surrounding air. The caps were rotated as needed to then put the ¼” steel rods through the 4 holes in each cap. These rods were fixed with ¼” hex nuts and the diffusion dryer was fully assembled (Figures 8 & 9).

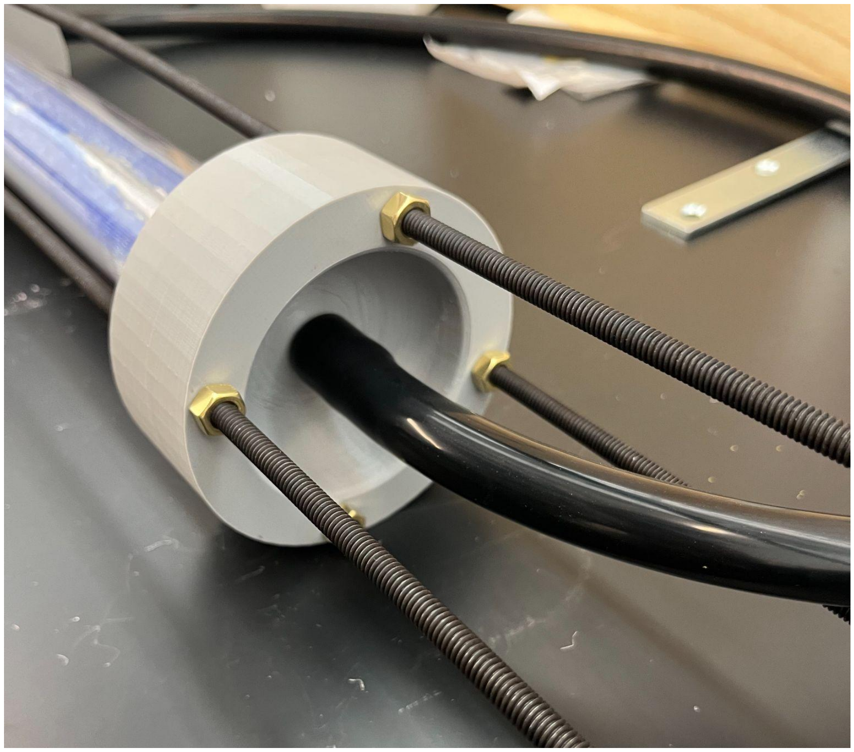

**Figure 8:** Assembled diffusion dryer with rods for additional sealing and security.

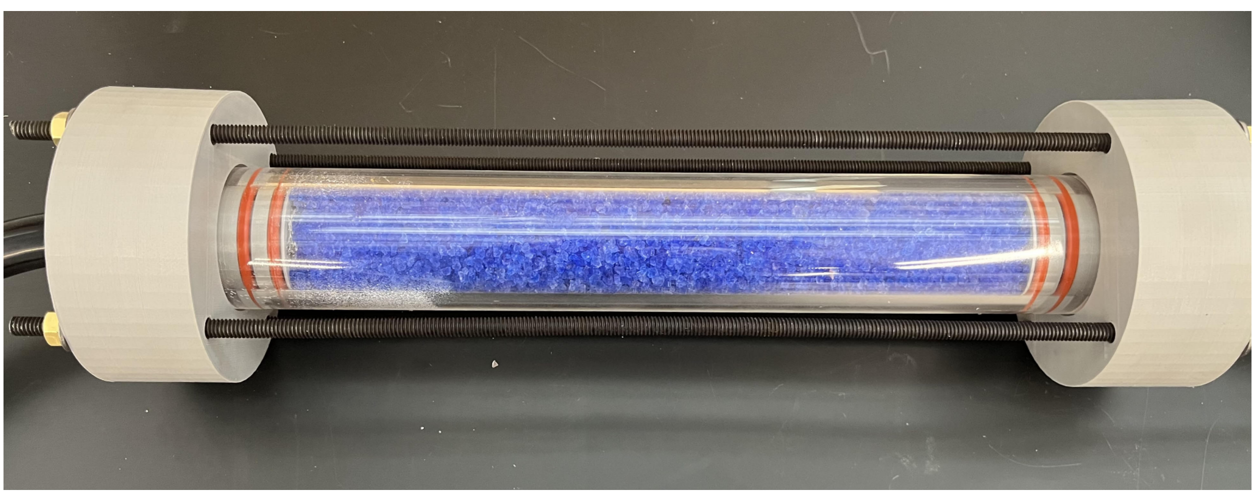

**Figure 9:** Fully assembled diffusion dryer.

**Testing**

To test the efficiency of the diffusion dryer, an oversaturated aerosol from the TSI 3076 Atomizer was sent through the diffusion dryer (Figure 10). A humidity sensor was placed at the outlet of the dryer to measure the change in humidity from the inlet to the outlet of the dryer (Figure 11).

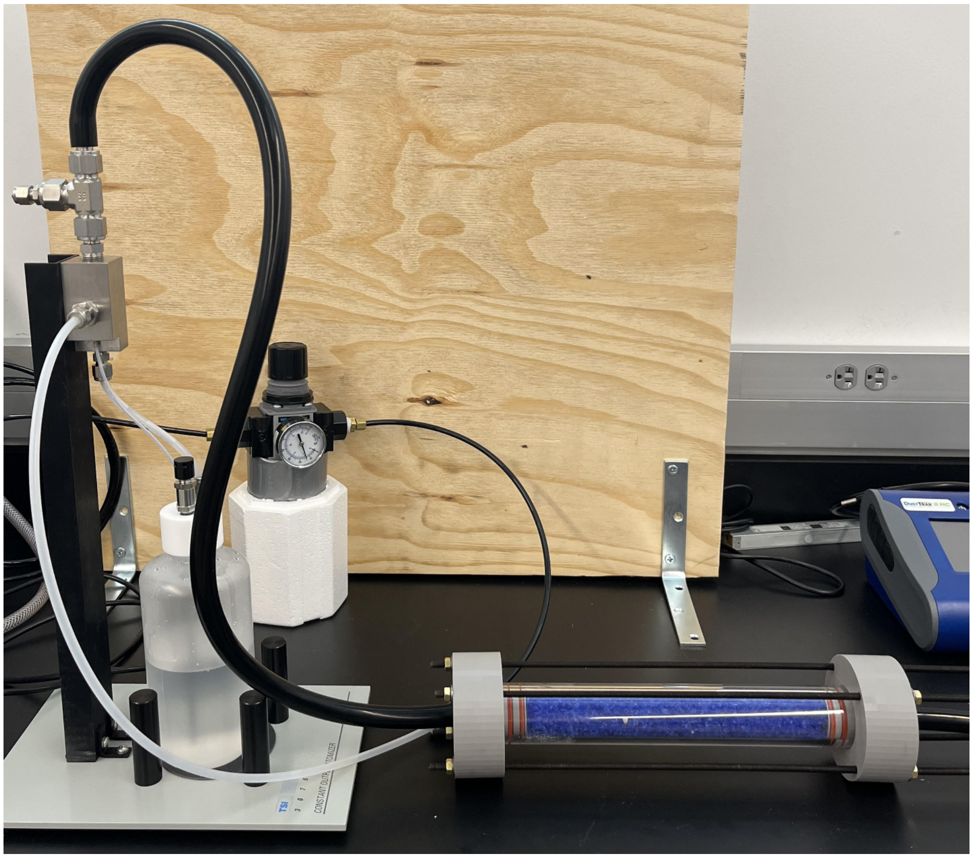

**Figure 10:** Aerosol setup consisting of a filter/regulator, atomizer, and diffusion dryer.


**Figure 11:** Humidity sensor to test the efficiency of the diffusion dryer.

The humidity of the aerosol exiting the atomizer was reduced from 100% to 72% humidity (Figure 11). This test illustrated the ability of the low-cost diffusion dryer to properly dehumidify the aerosol.

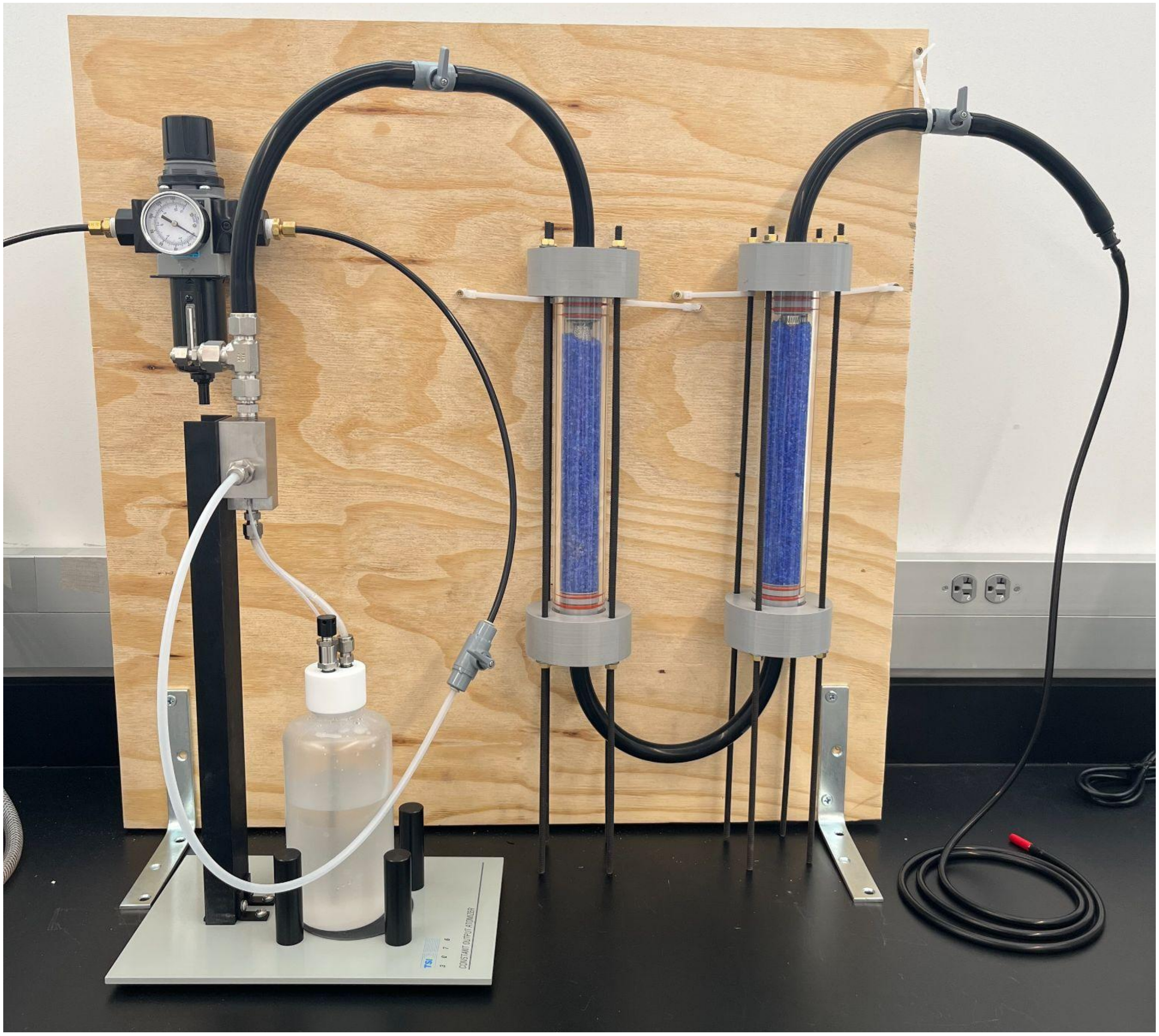

**Figure 12:** Two stage diffusion dryer aerosol setup.

To further dehumidify the aerosol, a second diffusion dryer was assembled. The humidity was tested again and it was found to decrease humidity from 72% after the first stage to 27% after the second stage (Figure 13).

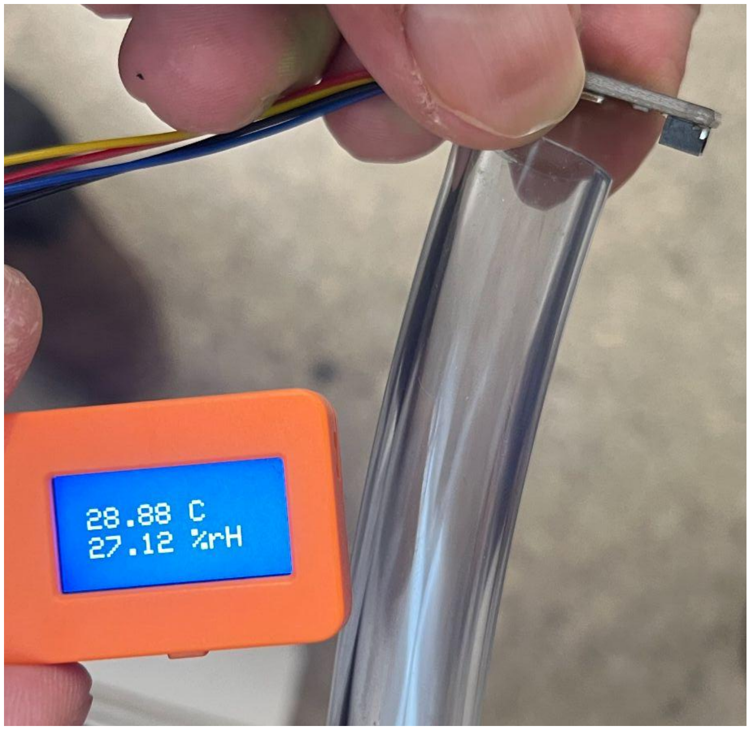


**Figure 13:** Aerosol humidity after 2nd diffusion dryer.