Get Wet: Nebulizer Spray

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This report details the work done on the project "Get Wet" for the course *Flow Visualization* at the University of Colorado Boulder. Flow Visualization is a course specifically meant for engineering majors fascinated in studying fluids and art majors interested in learning techniques to capture fluid flow through images and/or images. This can only enhance the student's capabilities on fluids projects in the future. Besides each person increasing their skills in their field, there is a large amount of cross flow in which engineers learn more about the artistic method and artists understand the physics of these flows better. The opposite effect happens as well. Get Wet is the second project of the course. The motivation of the image comes from the experience of conducting research work in the Larson Lab testing the filtration capabilities of an air cleaner. For this test, a collision nebulizer was used to spray an aerosol. Particle counters are used to check the concentration of aerosol that exists in the air through parts per million (ppm). The intention was to capture the smoke ring phenomena being emitted from the nebulizer.

Before explaining the physics flow, it is worth mentioning how the nebulizer generated the aerosol. In figure 1, the nebulizer is drawn out to show each specific component. First the gas pressurizes the inlet, which leads to the solution being drawn up the siphon tube. The high-speed jet pushes the solution out of the expansion channel, where it then hits the walls of the container. The larger particles fall back into the solution due to gravity, while the finer particles are emitted by the nebulizer.

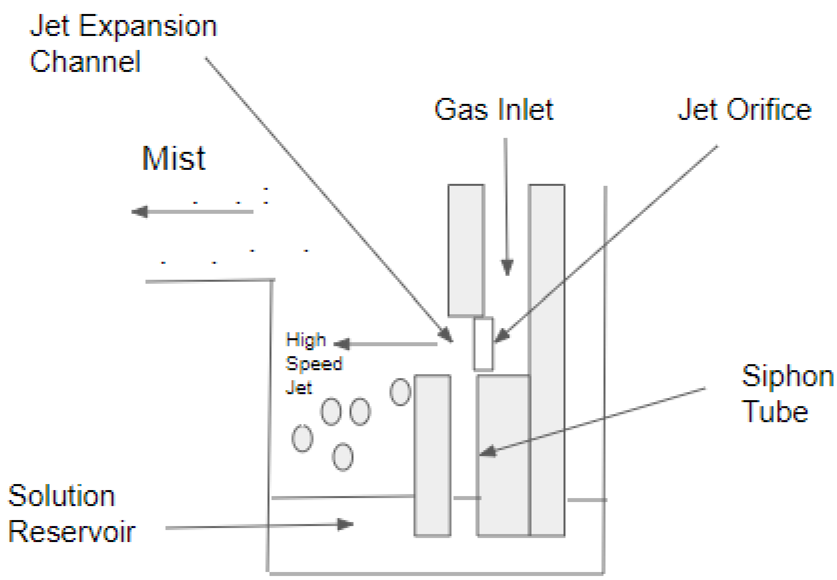

Figure 1: Diagram of a Collision Nebulizer

The finer particles appear as a mist as they are pushed out of the nebulizer nozzle and interact with the surrounding air of the room. The phenomenon that is taking place is the Rayleigh-Taylor instability, as the lighter mist is pushing the denser room air. The velocity of the air flow cannot easily be calculated from the pressure of the gas inlet because of the interaction between the highspeed jet and the wall of the container which slows down the flow. An approximation of flow velocity of 0.10 m/s is made, and the length of travel is about 0.30 m. An approximation is made by substituting the properties of water vapor for the KCl solution being used. With this substitution the density of the mist is then 0.7618 kg/m^3 and the dynamic viscosity of air is $1.825 \times 10^{-5}\ kg/(m \cdot s)$. Using these values to find the Reynolds number we have:

$$Re = \frac{\rho u L}{\mu} = \frac{(0.7618\ kg/m^3)(0.10\ m/s)(0.30\ m)}{1.825 \times 10^{-5}\ kg/(m \cdot s)}$$

$$Re = 1252$$

A Reynold's value of 1252 shows that at the point of 0.30 m with the approximations made, the flow is still laminar. Increasing the length, would increase the Reynold's value and place the flow into the turbulent flow category. Using a lower dynamic viscosity of just normal air could have contributed to the low Reynold's number and perhaps a better substitution could have been made.

As mentioned previously, a nebulizer attached to an air compressor with rubber tubing was used. The nebulizer was supplied by the air quality lab in the Sustainability, Energy, and Environment Community (SEEC) building on the east campus of CU Boulder. The air compressor was part of the Larson Lab. The tubing was supplied by the Larson Lab. The nebulizer was sprayed in an insulated test room that is part of the lab. The door to the room was open to the rest of the lab where some air was being supplied from a high supply vent. No air was being supplied to the room from the vents inside of the room. The nebulizer was spraying a water/potassium-chloride (H2O/KCl) liquid mixture. The ratio of the solution was 300 grams of KCl to every 1 liter of H2O). The compressor was set at a pressure of 20 psi, but decreased as the photoshoot took place. This was because an older air compressor was being used and the only way to pressurize it is to plug it into an outlet. The issue with this is that if it is not unplugged, it will just continue pressurizing. Room lighting was the only light used for this picture. The room is supplied by long fluorescent tubes in the ceiling of the room.

The distance of the object to the lens was 1.5 feet. The picture was taken with a Canon EOS 40D on a 50mm lens. The camera setting for this image was a f-stop of 1.8, the ISO was set to 400, and the shutter speed was 1/60 s. The image's brightness, contrast and lighting were manipulated in the re-touching stage.

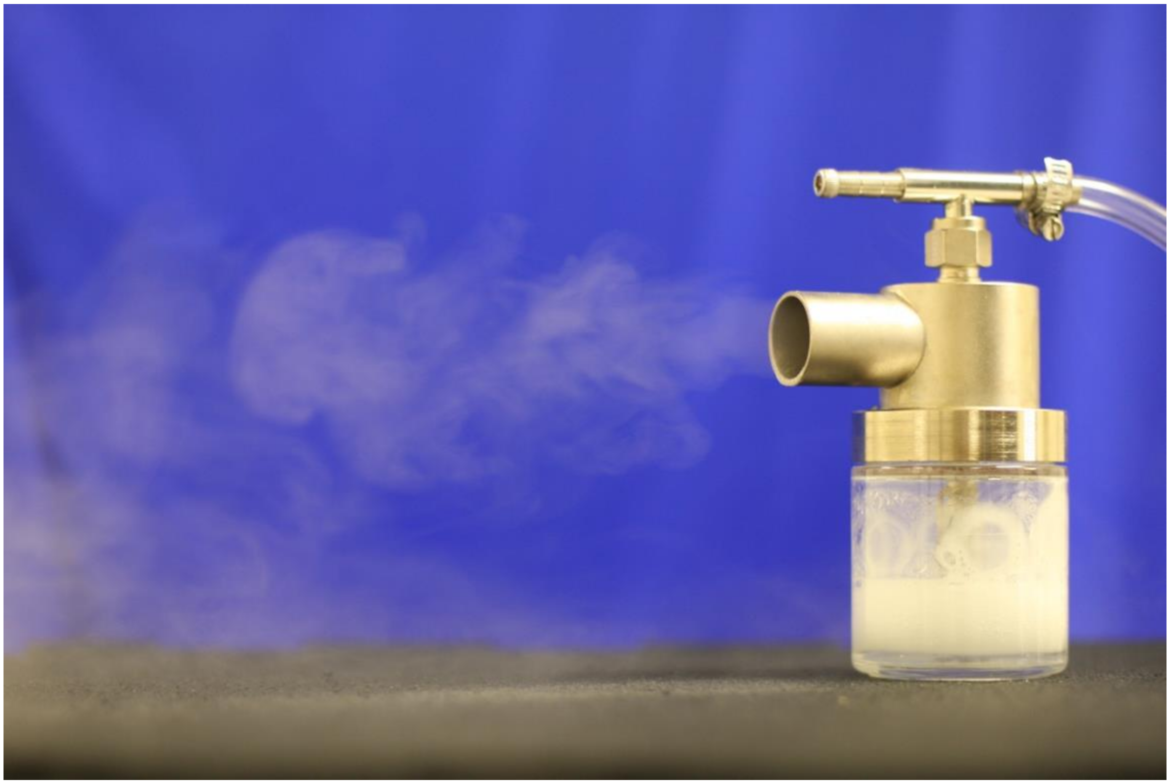

Figure 2: The Image before editing.

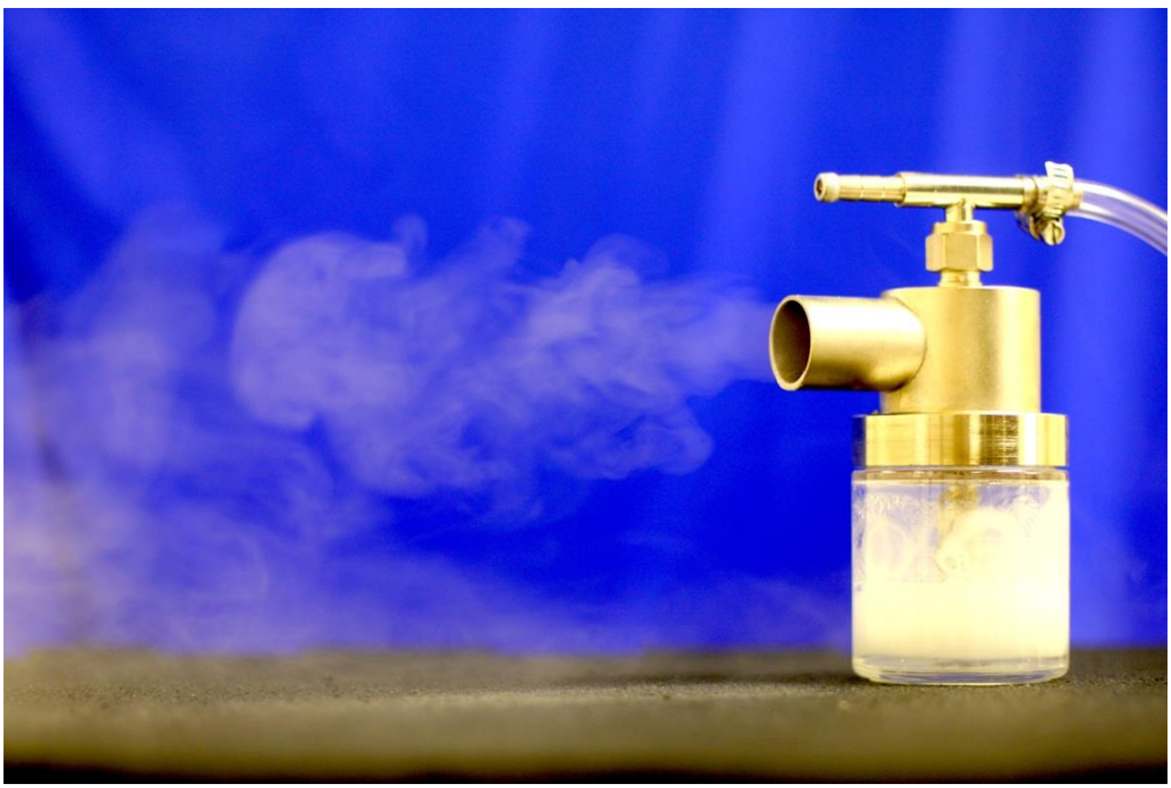

Figure 3: The image after editing.

The image reveals the instability of the flow in a room in which the air flow is not controlled. The parts I like about the image are that it shows the flow of vapor from the nebulizer in the type of stream that I wanted to capture. Initially I wanted to get a smoke ring, however I saw that that was done in previous years, and I did not want to spend a lot of time around secondhand smoke. I think it is interesting how the vapor seems to move back and forth as it moves forward, meaning the flow is not linear and there are spatial changes in the air flow that are not linear. With air moving in one direction, it will move forward and reverse as well. I also like how I was able to capture a complete section of diffusing within the frame of the shot. I do not like the fact that the nebulizer is in better focus than the aerosol being sprayed out of the nebulizer. By using the ruler trick, this aspect could have been improved. The main aspect I would like to improve is creating a clearer contrast between the aerosol and the background. A darker background, better illumination, and altering the shutter speed and ISO could have produced this effect. To further develop the idea of tracking smoke flows, I would try burning different items with various controlled conditions to see what has the most dramatic visual smoke. From there I would figure out the type of flow I was working with and see how I could further alter the flow. I fulfilled most of my intent by capturing air flow that had similarities to a smoke ring. My main question is how to better control the air flow in a room with variable movement? I am thinking what I could do is start a sequence of smoke, see where it travels, and then use manual air flow to move the smoke in the way I want it to be moved.

Reference:

Engineer's Edge, "Viscosity of Air, Dynamic and Kinematic"
https://www.engineersedge.com/physics/viscosity_of_air_dynamic_and_kinematic_14483.htm