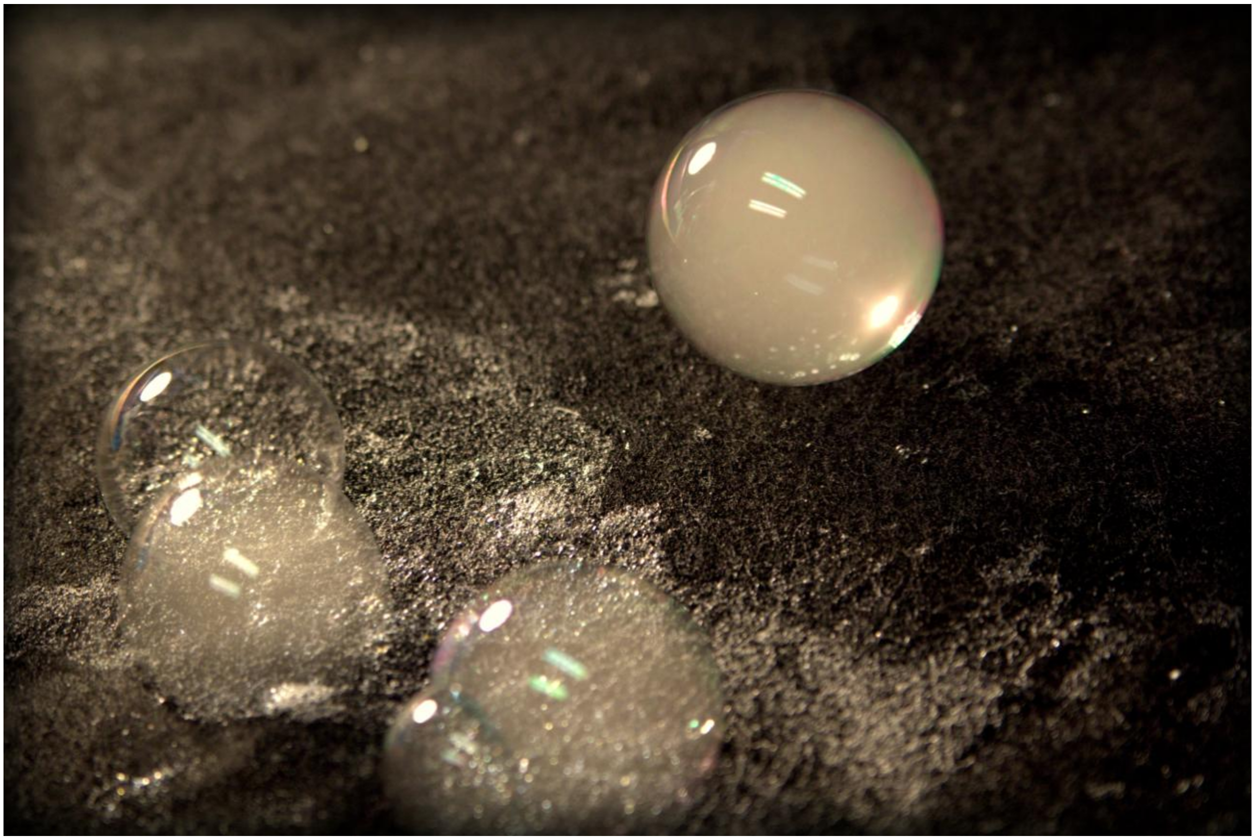
Group Project #2



Kerylyn Lay

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1.0 Introduction

The purpose of this report is to describe the physics behind a flow phenomena, visualization techniques, and photographic techniques used for the second group project. For this assignment bubble formation and condensation of water vapor out of air was used as the flow phenomena, and achieved by using liquid nitrogen to create the water vapor that was then used to blow soap bubbles as seen on the cover of this report. The following text describes the physics behind how bubbles form and how the water vapor forms when air comes in contact with liquid nitrogen. It also describes how the flow was achieved, and photographic techniques used to achieve the best possible picture.

2.0 Experimental Setup

For this experiment a glass measuring cylinder roughly 8” tall with a 1” diameter, similar to the one shown in figure 2.0-1, was filled with about 1” of water to start. One end of a 2’ long 0.25” diameter plastic tube was placed into the cylinder, but not touching the water, and the other end was dipped into a concentrated water-liquid dishwashing soap solution with a mixture ratio of 1:1. A black felt material was placed on a desk to create a dark surface that the bubbles could be blown onto once the experiment started and a spotlight was placed above the black surface for lighting along with the florescent lights that already existed in the room. Liquid nitrogen was then poured into the measuring cylinder and a towel was placed over the top of the cylinder in order to force the evaporating nitrogen gas and water vapor through the plastic tube, thereby, creating bubbles through the end that was dipped in the soap mixture. A camera was held roughly 5 inches away from the bubbles at roughly a 20° elevation angle in order to get the best lighting. Figure 2.0-2 shows a diagram of the experimental setup.

Figure 2.0-1 Measuring Cylinder Similar to the one used in Experiment

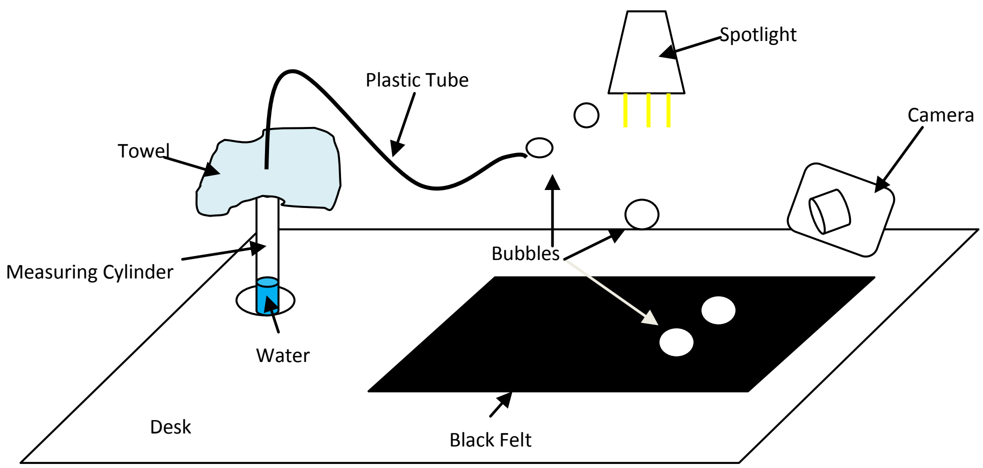

Figure 2.0-2 Experimental Setup

3.0 Description of Flow Physics

Soap bubbles form from a thin film of soap containing a volume of air, or in this experiment water vapor. The surface tension of the soap film shrinks the volume it contains into a shape that has the smallest possible surface area[4]. This is why singular bubbles take on the shape of spheres. Table 3.0-1 shows examples of surface area from different shapes that contain the same volume, the sphere being the smallest.

Table 3.0-1 Surface Area of Various Shapes Containing the Same Volume [1]

Shape	# of Sides	Volume	Surface Area
Tetrahedron	4	1 in^3	7.21 in^2
Cube	6	1 in^3	6 in^2
Octahedron	8	1 in^3	5.72 in^2
Icosahedron	20	1 in^3	5.15 in^2
Sphere	Infinite	1 in^3	4.84 in^2

When two bubbles are connected they will form a flat surface if they are the same size or if different sizes the smaller one will bulge into the larger one due to its higher internal pressure. This can be seen in the bottom left bubbles on cover image. Sharing a common wall again minimizes the surface area of the two bubbles. If more than two bubbles are connected they will always meet at the common wall with the other bubbles at a 120° angle, known as Plateau border [2]. This rule creates the hexagon shapes that are seen when multiple bubbles are collected, like in foam. This picture does not demonstrate this phenomenon due to only capturing singular and pairs of bubbles.

Liquid nitrogen boils at -371°F and must be contained in an insulated vacuum chamber to keep it in liquid state. When liquid nitrogen is exposed to the air it begins boiling off into cold nitrogen gas because the air temperature is above the heat of vaporization of the liquid nitrogen. During the phase change from liquid to gas the temperature remains the same as the enthalpy increases so the nitrogen gas as it first boils off should be -371 °F. The gas is cold enough to cool the air below the dew point, and water vapor is condensed out of the air creating a fog. This photograph was taken on March 20, 2012 at around 4pm. The air conditions for that day were 51.8°F with a relative humidity of 20% [3]. Using a psychrometric chart, the dew point or saturation temperature of the air during the experiment was 8.6 °F. The nitrogen gas is well below the dew point of the air and is able to condense water vapor from the air. Since the relative humidity was so low the day of the experiment, water was placed at the bottom of the measuring tube helps increase the humidity creating a thicker fog.   As the liquid nitrogen boils the evaporating nitrogen gas increased the pressure in the measuring cylinder that was sealed with the towel and pushed the water vapor through the plastic tube creating bubbles that were filled with the water vapor. The bubbles shown in the picture that are not filled with the water vapor are from the initial air that is evacuating the tube in front of the water vapor.

4.0 Photographic Technique

A Canon EOS Rebel T2i 18 MP camera was utilized for this photograph. The 100 mm macro lens was used in order to get a clearer close up photograph. The field of view of the photograph was roughly 5” x 4” and the camera was placed roughly 5” from the bubbles. The focus mode was set to manual with a focal length of 75 mm. Aperture was set to F/4 with the camera exposure mode set to aperture priority. The shutter speed was 1/100s and the ISO was 640. Figure 4.0-1 shows the before and after gimp processed photograph. Post processing in gimp included increasing the contrast slightly to darken the black area and brighten the look of the bubbles. Some cropping was done to remove unwanted area on the edges.

Figure 4.1 Post and Pre Processing Photograph

5.0 Conclusion

This image shows the formation of bubbles and captures the fog that is created by liquid nitrogen as it interacts with the air around it. The singular bubble demonstrates how a spherical shape minimizes the surface area containing a volume of gas and the double bubbles show how the small bubble bulges into a larger bubble at a common wall due to high internal pressure. The main bubble in the photograph contains water vapor and demonstrates how liquid nitrogen cools the surrounding air to the saturation temperature so that fog can form. The biggest issue with this assignment was figuring out what experiment to do with liquid nitrogen that would create a compelling photograph. Several experiments were tried including freezing balloons, but the bubble photographs produced the best images mainly because the contrast of the white bubbles with the black surface and the reflecting light on the soap film.

6.0 References

1. R. Hipschman, "http://www.exploratorium.edu/ronh/bubbles/bubbles.html"

2. J.E. Taylor, "The Structure of Singularities in Soap-Bubble-Like and Soap-Film-Like Minimal Surfaces," The Annals of Mathematics Second Series, Vol. 103, No. 3 (May 1976).

3. http://www.wunderground.com/

4. http://en.wikipedia.org/wiki/Soap_bubble