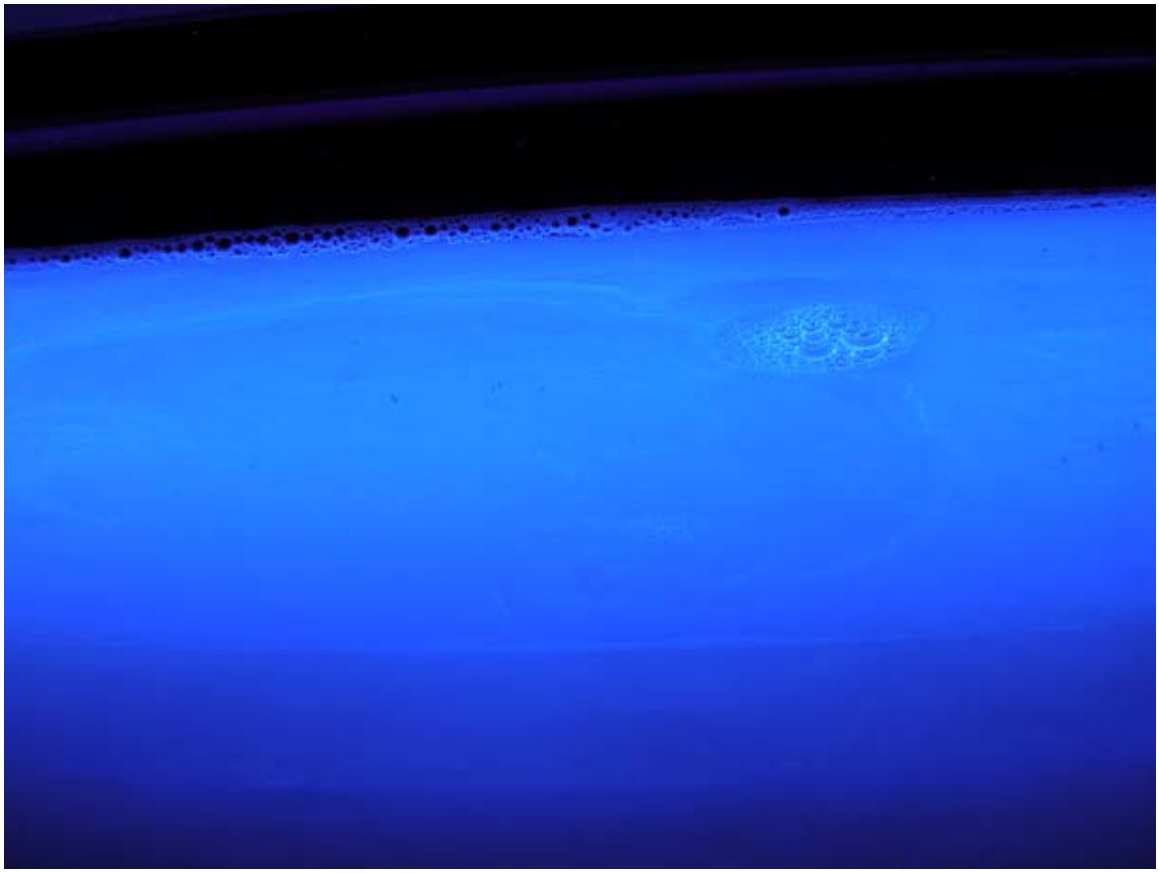
"GET WET"



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Flow Visualization MCEN 4228
Professor Jean Hertzberg
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Context and Purpose

The original photographical intention was to capture the body flow characteristics of a vortex ring in a fluid with a higher viscosity than air. The thought process behind this idea was the higher viscosity of the chosen fluid, water, would allow for the ring to have laminar flow rather than the highly turbulent flow present in smoke vortices in air. However, science is not always an exact process and discoveries other than the original intention occur within the mishaps of the original experimental procedure. A series of grouped bubbles and swirls consisting of the visualization fluid formed on the surface of the testing apparatus as an indirect effect of the repeated motion in formulating the fluid vortices. This new phenomenon, grouping or clustering of bubbles in a moving fluid, is the concentration of this paper.

Apparatus and Theory

The apparatus used to capture the image consisted of the following:

- Fish Tank
- Vortex Generator
- Black Light
- Black Cloth or Paper
- Visualization Fluid

The fish tank was filled to the top with water and placed on a table with access the sides. The moving nature of the fluid required that the camera be placed perpendicular to the length biased to the opposite side where the generator was placed. This allowed for the fluid flow to be captured while keeping the generator out of the photograph. The black light was placed on top of the fish tank along the wall opposite the camera. A visual representation of the apparatus can be seen in Figure 1.

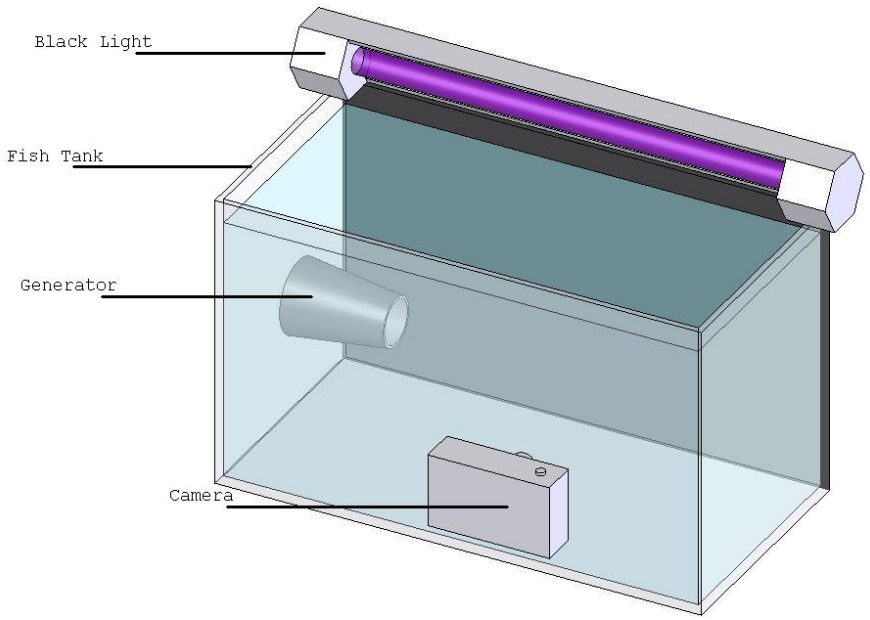

Figure 1: Apparatus

The photograph is a picture of very slow if not stagnate flow which was a result of the perturbation of the two mixed fluids when using the generator. The minimal movement of the fluid allowed for the resolution to be maximized within the picture without motion blurring. As a reference the main cluster of bubbles off center to the right was measured to be 1.25 inches in diameter. There are two questions to answer: why are the bubbles all clustered and not spread apart? Why are the bubbles larger in the center of the cluster? The answer to both questions lies in bubble coalescence. According to Roman Durikovic, alike atomic arrangements in a lattice, it is found that when the centers of two bubbles of the same size are separated by a distance that is large compared with the diameter of the bubbles, the force of attraction is very weak. As the separation distance decreases the force of attraction increases and reaches a maximum when the bubbles come into contact[1]. Removing an object from the test fluid created natural spiral currents of which the bubbles followed and met connecting to each other through bubble coalescence. This spiraling motion can be seen by observing the surrounds of the bubble cluster. Though Durikovic did not specifically state why bubbles of larger size are centrally located within the cluster, a reasonable guess can be made: As the bubble diameter decreases the attraction of the bubbles decrease. The larger bubbles attract and form in the center because of the larger attraction force between them. Subsequently, the bubbles decrease as the radius of the cluster increases because of the smaller attraction the bubbles have with each other.

Visualization Technique

To make the fluid mixture taken in the photograph ALL Stainlifter laundry detergent was poured into the vortex generator and then dunked into the tank. The vortex generator was made of a yogurt cup with rubber bands attached to a plastic bag. Details on the construction are not vital because pouring the same amount of detergent into the water and hand mixing would yield the same affect. In taking the photograph the proportions of the detergent to water are not exactly known. Because the initial objective was to visualize ring vortices the amount of fluid was not of major concern and was not directly measured. An estimate can be made by measuring the cup used to poor the detergent into the generator. A rough measurement yielded about 1.5 cups of detergent was used before the photograph was taken. The fish tank was 20x10x12 inches. This corresponds to 166.23 cups. This yields a mixing ration was around 0.009.

The only lighting used was a single 24 inch fluorescent black light positioned at the top rear of the tank as seen in Figure 1. The studio was kept completely dark except for the black light. The flash on the camera was suppressed and only the aperture and exposure time were altered to take the photograph.

Photographic Technique

After taking the picture of the ring vortices the camera was rotated about the tripod to capture the photograph discussed in this paper. To capture the picture the zoom was used to confine the field of view. A very important note is that the photograph was taken from underneath the fluid through the side of the fish tank not perpendicular to the wall. The camera was moved roughly 45 degrees about its vertical

access and then 45 degrees about its horizontal axes from the original position on the tripod and the result is shown in Figure 2.

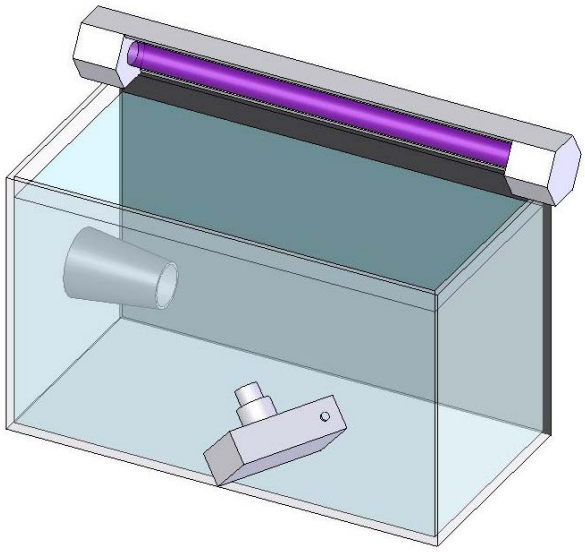

Figure 2: Camera Position

The back of the fish tank was covered in black cloth to prevent reflection. A good measurement reference within the photograph is the black rim of the fish tank measured at 3/4 inch not featured in the drawings of the apparatus but apparent in the photograph. This can be seem at the top left of the photograph above the faint blue mostly horizontal streak within the dark region. The following bulleted list summarizes the equipment and characteristics of the camera used to take the photograph:

- Field of view: 11.25x8.6 inches
- Distance from object to lens: 9 inches
- Lens: 28mm, Wide Converter Nikon WC-E80 0.8x
- Camera: Digital, Nikon COOLPIX 5700
- Exposure: Aperture F2.8, Exposure 1sec
- Resolution: 2560x1920

Image Context and Conclusion

The image taken reveals several aspects of science. The most important is the phenomenon of bubble clusters forming from the natural currents created by the perturbation of water and the coalescence between bubbles. Another main point to make is that the image represents an accidental discovery of a phenomenon, which is not uncommon in science. The original intent was to take an image of something entirely different, however, failing to make one idea work lead to another unexpected discovery.

One perk about the image is that it was taken without any intention of using it, but this is also bothersome. While the image turned out to be pleasing to the eye and scientifically informative, the underlying feeling of frustration with the failure of the original intent is still present. Putting all that aside, one of the major aspects of the

photograph that stands out is the contrast of the black upper section to the fluorescence of the fluid. From afar it almost looks like some of the nebula is outer space studied by astrologers which form similarly to bubbles.

Further studies on the subject of bubble cluster formation should be done to look at the effects of different flows within the fluid. Examples would be faster circulation and constant flow to see how the bubbles react to stronger body forces. Another possibility is the study of the effects of walls on the formation of bubble clusters.

Overall the original intent of the project was not met, but a very acceptable end product was obtained. In the future, more thought should be applied to the design of the apparatus to insure that the photograph turns out in the desired fashion.

References

1. Durikovic, R. (2001) ‘Animation of Soap Bubble Dynamics, Cluster Formation and Collision’, *Computer Graphics Forum*, 20/3: c/67-c-75.