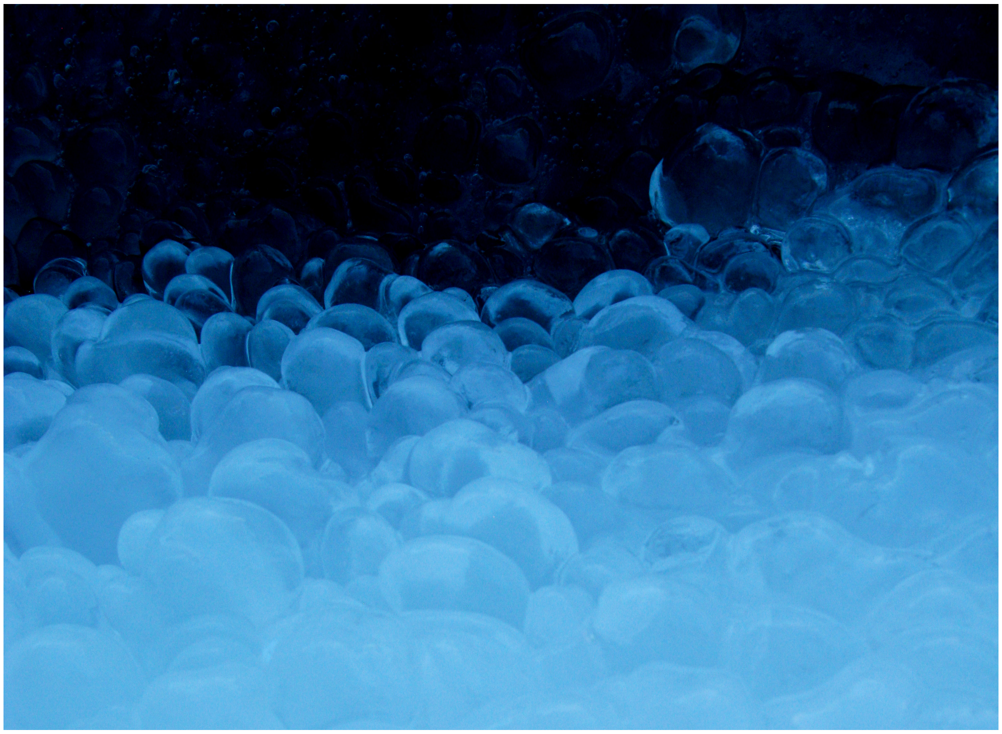
Get Wet 1: Ice Bulbs

Hayley Schneider
University of Colorado Boulder -Department of Mechanical Engineering, Flow Visualization



This image, *Ice Bulbs*, was created as a part of the *Get Wet* Assignment for the University of Colorado MCEN 4151: Flow Visualization course. This was the first assignment of the Spring 2012 semester. The purpose of this assignment is to get students to begin considering the possibilities of flow visualization and to "get their feet wet" as they begin to explore the kinds of images they can capture for the class.

"Ice Bulbs" is an image visualizing the formation of ice as it wets against a metal surface. The photograph was taken at the bottom of a 25 foot vertical gutter outside on a day with below freezing temperatures. The exhibited flow shows surface wetting and freezing by fine liquid particles. The resulting "ice bulbs" range from 0.3-1.0 inches in diameter.

The image was taken outside of the warehouse located at 40.016539 N,-105.224476 W on February 6, 2012. This day was proceeded by two days of snow and below freezing temperatures. On February 6 the temperature began to rise (high of 31ºF), however, it was still below freezing. The radiation from the sun melted the snow and ice on the roof of the building and caused it to flow down the gutter. The gutter had been partially jammed with ice, so the water began taking an alternative waterfall-like path. The water fell from approximately 25 feet, hitting various obstacles throughout its fall, creating a fine mist of water droplets by the time it came into contact with the ground. It appeared that the water was also splashing from the ground and the puddle at the bottom of the gutter back onto the wall of the building. This is where the exhibited fluid phenomenon was discovered. The setup in this location can be seen in Figure 1.

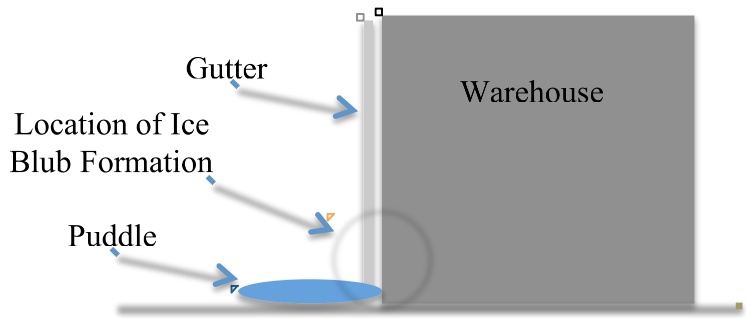


Figure 1: Schematic of ice bulb formation location

The phenomenon of "ice blubs" occurred on all sidewalls of the puddle, and was most prevalent on the wall connected to the side of the warehouse. Figure 2 shows the puddle where the ice bulbs were formed.

Figure 2: Puddle where ice bulbs formed

Figure 3 shows the original image with the scale shown. This is a photo of the circled area in Figure 2.

Figure 3: Large scale and original image

In order to determine the dimensionless number applicable to this situation, it is first necessary to determine the velocity of the water as it splashes in the pool. The diameter of the jet of falling water is assumed to be 0.01 m in diameter. To determine the velocity of the jet, the volume of a spherical drop is determined in Equation 1.

Equation 1

$$V = \frac{4\pi r^3}{3} = \frac{4\pi (0.005\ m)^3}{3} = 5.2\times10^{-7} m^3$$

Using the volume in combination with the density, the mass of a droplet can be determined. The density of water at 33ºF (0.55ºC) is 999.9 kg/m³ (Bellows 2009). Equation 2 shows the mass calculation.

Equation 2

$$m = V\rho = (5.2\times10^{-7} m^3) * \left(999.9\frac{kg}{m^3}\right) = \mathbf{0.00052\ kg}$$

Assuming a 25 foot (7.62 m) freefall, the final velocity of the drop is 12 m/s.

The Reynolds number for this flow can be determined. The ambient conditions are assumed to have the water is at 33ºF, a temperature selected where liquid is just above the freezing point. The characteristic length will be 1 cm, the assumed diameter of the falling jet of water as it melts off the rooftop. Viscosity is 0.00176 Pas (Bellows 2009).

Equation 3

$$Re = \frac{UD}{v} = \frac{(12\frac{m}{s})(0.01m)}{0.00176\ Pas} = 6.82$$

The bottom of the ice puddle was asphalt, lending nicely to flow visualization. The image was taken in indirect sunlight (shade). The camera was covered (apart from the lens) with a plastic bag to prevent water damage due to the falling stream and mist of water.

The size of the field of view was approximately 3 feet across. Ideally, a smaller field of view would have been used, however, due to the setup of the image, it was not possible to obtain a smaller field of view. The distance from the ice bulbs to the lens was approximately 1 foot, again this was restricted by the setup of the physical objects. The original image is 4000 x 3000 pixels, the maximum resolution available on the Canon PowerShot G9. The focal length is 7.4 mm. The aperture for this image is 4, the shutter speed is 1.250 and the ISO setting is 80, lending to the particular focus and depth of field seen in the image.

This image was post-processed using Photoshop. The image was cropped and rotated. The contrast was then increased, resulting in a bluer image, accentuating the "coolness" of the ice formation.

Exploring and researching the formation of ice bulbs was not very fruitful. There are very few experts in this particular field and this phenomenon has mostly been captured by independent amateur photographers at the base of misty waterfalls. Ideally, this image would be replicated in a laboratory environment; however, the resources available do not lend themselves to this setup. An experimental setup would contain a cooled plate (ideally by a liquid nitrogen plate cooling system), and a mister with particulates of either carbon or another fine dust to stimulate crystal formation. This would be an excellent experiment for a future flow visualization group to perform.

Sources

Bellows, J. C., et al. *ASME International Steam Tables for Industrial Use*. (2nd ed.) American Society of Mechanical Engineers, U.S., 2009.

Kreith, Frank, R. M. Manglik, and Mark Bohn. *Principles of Heat Transfer*. Stamford, CT: Cengage Learning, 2011. Print.

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