

THIS is the HOTV BREWSLETTER

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Last Month :

The April meeting took us to the hillside home of our current President, Jerry. The sun made a brief appearance, and we all toasted its radiant warmth. There was even a strange man with very short, light colored hair. Rumor has it that strange individual was Ted, but I still don't believe it.

We sat down to business and listened to festival progress reports. Confident committee chairs cheerfully chimed their achievements. Facilities are in order, and trucks have been reserved. Gracious businesses have donated fabulous prizes for our annual raffle. The food will be properly handled, and you won't have to pay extra for sauerkraut. Announcements have gone out, and the newspapers have been contacted.

After this grueling session of business, we had still more work to complete. Brewing Techniques Magazine has arranged an interesting exercise. Eight local breweries got together and formulated a recipe. The group purchased grains and hops as a group, then each picked up their share. Once at their respective ale houses, each brewer used their own techniques and house yeasts to facilitate the recipe. The result was eight different American Pale Ales that needed to be analyzed; to be compared and contrasted. Our poor group of humble palates were up to the task. We assembled a team of stewards, and many others participated in what turned out to be a very interesting, difficult, and fun exercise. See Brewing Techniques Magazine for results.

Upcoming Event in Salem:

Capitol Brewers have a up-coming event that may be of interest to any or all of HOTV. Their May meeting will be at Eric Munger's home on May 7th at 7:00pm. 1554 Scotch Ave. SE, Salem, (503) 362-1728.

Their anticipated guest speaker will be Dave Logsdon from Wyeast Labs. Two years ago when Dave came to their meeting he shared some great info on aeration, answered questions from the group, and (dare I say) had some generous freebies. They will also be determining their club's Best of Bock entry.

Dave's appearance looks firm at this time, but you may want to check with Steve Warren (the Prez) prior to coming up. His number is (503)-364-7916.

This Month

Heart of the Valley Homebrewers hold regularly scheduled meetings. We welcome one and all to come participate in the difficult business of talking about (and drinking) beer. The appointed hour comes at seven sharp, in the evening of course. We meet on the third Wednesdays of each month.

The regular meeting for the month of May will be held at the home of our past president, the person responsible for taking over festival organization, the Albany Cajun, none other than Lee Smith. The address is 2190 Mair Lane, Albany Oregon. DIRECTIONS:

From Corvallis: Take Highway 20 almost to the Albany city limits. Turn LEFT on SCENIC DRIVE. Follow this around until the stop sign, then turn RIGHT on GIBSON HILL ROAD. Follow this for a short spell until you see SKYLINE DRIVE on the right; turn there.

From Albany: NORTH ALBANY ROAD becomes GIBSON HILL ROAD. Follow this until you see SKYLINE DRIVE on the left, turn there.

From Skyline Drive: Go up to MAIRLANE DRIVE on the Left and turn there. Fork to the right (there should be a smallish sign), 2190 is the last house.

[A Map to Lee's](#)

June Cleaning

June 7 is the next scheduled highway cleanup. Details will be shared at the May meeting, but be prepared to volunteer a couple of hours to help keep our little adopted road free of litter. This is an enriching event that always leads to a cool pint....

Excerpted from

Through A Beer Glass Darkly

Neil E. Shafer and Richard N. Zare
Physics Today. October 1991. Pages 48-52.

Equations, figures, and tables have been omitted for simplicity. If you are interested, I can get a copy to you.

Pour yourself a glass of beer and look closely at the rising bubbles. Careful examination shows that they are seldom distributed uniformly throughout the liquid. Instead, streams of bubbles appear to rise from certain spots on the surface of the glass. Closer inspection reveals that the bubbles rapidly grow in size as they ascend, the volume of each bubble often doubling or more by the time it reaches the top of the glass. In addition, the speed of the bubbles increases as they travel upward.

You might think that in the several millennia that beer has been with us we would have already learned all there was to know about this curious brew. Yet a glass of beer reveals a remarkable interplay among gasses, liquids, and solids, temperature, pressure and gravity -- an interplay that is still not completely understood. Once you begin to learn about the nature of beer bubbles you will never again look at a glass of beer in quite the same way.

Fresh beer will go flat in an open container as the carbon dioxide produced during fermentation escapes into the atmosphere. To prevent this, beer is kept in sealed bottles or cans so the CO₂ is trapped. Some CO₂ molecules collect under the cap or lid, until the pressure inside the container reaches two or three times the pressure of the atmosphere. Other CO₂ molecules remain "free floating" (dissolved) in the liquid. Pop off the cap from a beer bottle or pull the tab on a beer can and --fizz-- trapped CO₂ gas rushes

out. The equilibrium is broken.

Pour the beer into a glass and bubbles appear. But how do these tiny gas pockets form? Visible bubbles begin as invisible clusters or microbubbles of CO₂ molecules that grow on rough spots, called "nucleation sites," where the CO₂ molecules can attach themselves and coalesce. In fact, the formation of beer bubbles is very similar to the formation of rain clouds, in which rain droplets grow on dust particles. Indeed, we can promote the bubbling of beer by introducing artificial nucleation centers such as grains of sugar, salt, or pepper (ugh!), just as Donald Glasser introduced elementary particles into a bubble chamber to leave a track of nucleation centers. Before succeeding with the superheated diethyl ether bubble chamber, Glasser half-seriously tried out his bubble-chamber ideas by opening bottles of beer, ginger ale, and soda water in the presence of a radioactive source. In the most impressive of a series of recent experiments at the University of California at Berkeley's Bevatron, Frank Crawford introduced 2×10^7 Fe²⁶⁺ particles with energies of 600 MeV/nucleon into a glass of beer every 4 seconds to try once more to find ionizing-particle-induced beer bubbling. NO bubbles were found.

Instead of relying on foreign particles to start beer bubbling, we can let the surface of the glass provide nucleation sites. At rough patches or microcracks on the surface, where CO₂ molecules have a chance to accumulate, bubbles form. Often one sees whole strings of bubbles streaming gracefully upward from these nucleation sites.

Rapidly Growing Bubbles

But what makes bubbles grow as they rise? One might suppose that the drop in hydrostatic pressure accounts for this behavior. Recall, however, that some of the bubbles double in size as they ascend. If a drop in pressure were responsible for this bubble growth, the pressure on a bubble at the bottom of the glass would have to be twice as great as the pressure on a bubble near the top -- that is, 2 atmospheres rather than 1. But a bubble would have to rise roughly 30 feet for the pressure to drop this much. Thus the pressure-change hypothesis is wrong for a 12-ounce glass of beer. The correct explanation for bubble growth is that bubbles accumulate carbon dioxide as they ascend through the beer. In other words, bubbles act as nucleation centers for themselves.

After a bottle of beer is opened, the partial pressure of dissolved CO₂ in the beer is greater than the pressure of the CO₂ in the bubble, and the dissolved gas travels from the beer to the bubble. Because this pressure difference remains almost constant, we expect (to a good approximation) the rate of bubble growth to be proportional to the surface area of the bubble. This is valid only because the beer maintains the bubble at constant temperature and the atmosphere maintains the bubble at a constant pressure (the hydrostatic pressure of the beer being negligible).

Assume the CO₂ obeys the ideal gas law $PV = NRT$. Because pressure and temperature are constant, we can differentiate both sides of the ideal gas law with respect to time and describe the rate of increase of the bubble's radius.

A stream of bubbles provide data for a wonderful test of our bubble-growth model. At the origin of the stream, CO₂ molecules collect at a nucleation site until the resulting bubble reaches a critical size and is able to break away. As soon as a bubble is released, another one starts to form. Because each bubble undergoes the same formation process, the bubbles are released at roughly equal time intervals. By measuring how long it takes for a number of bubbles in the string to reach the top of the glass, the time between adjacent bubbles can be calculated in absolute terms. For one stream of bubbles, we observed that 107 ± 4 bubbles reached the top of the beer in 58 seconds, indicating that a bubble was released from the nucleation site every 0.54 ± 0.02 seconds.

Care must be taken in studying the size and shape of beer bubbles. Because the beer and glass act as a lens distorting the images of objects viewed through them, the bubbles are actually smaller than they appear. To compensate for this distortion, we placed next to the stream of bubbles a copper wire 0.26 cm in

diameter and notched every 1.02 cm, and then photographed the bubbles. We measured the height of the bubbles $z(t)$ with respect to the notches in the wire; we measured the radius $r(t)$ of the bubbles by enlarging the photograph and comparing the horizontal width of the bubbles to the width of the wire. A linear fit to these data indicates that r_0 (the initial size of the bubble) was equal to 0.018 ± 0.004 cm and that the radius of the bubble grew at a rate νr of 0.004 ± 0.001 cm/sec.

Buoyancy versus drag

What cause a bubble to rise? The answer of course is that the density of a CO₂ bubble is less than the density of the surrounding beer. The buoyancy force F_b is proportional to the volume of the beer displaced by the spherical bubble (Archimedes' principle). We use the approximation that the density of the CO₂ gas is much less than that of the beer. If we also assume that the bubble moves slowly enough and is small enough that its shape remains spherical, we can relate the buoyancy force to the radius of the bubble.

As a bubble rises, it encounters resistance, or drag. In general, the drag on a rising bubble is a complicated function of its radius and speed dz/dt as well as of the viscosity, density, and surface tension of the liquid it is in. If the ascending bubble had a fixed size, it would reach a constant, or terminal, velocity at which the buoyancy force exactly counterbalanced the drag force. But because the bubble's radius is always increasing, the drag force, which increases less rapidly than the r^3 , can never quite catch up to the buoyancy force, which is proportional to r^3 . In other words, the upward buoyancy force increases more quickly than the downward drag force, causing the bubble to accelerate. This explains why in a stream of bubbles rising from a nucleation site on the beer glass, the bubbles near the bottom are smaller, slower, and more closely spaced than those near the top.

A differential equation is developed using the buoyancy force, the internal forces on the bubble, and the drag force to predict the motion of the beer bubble. A solution of this equation is independent of the initial velocity of the bubble. Just as in the case of a marble falling to the bottom of a jar of molasses, the trajectory of a rising beer bubble is almost independent of the initial velocity of the bubble. In the case of a marble in molasses, the velocity almost immediately assumes a constant value, whereas in the case of a beer bubble, the velocity almost immediately assumes a functional form that is dependent only on the bubble's radius.

Because it is so difficult to determine the theoretical drag F_d on a particle moving in a viscous medium, to predict the motion of such a particle we must rely on empirically determined correlations. These correlations are customarily made between various dimensionless parameters, the most familiar of which is the Reynolds number R , the ratio of inertial to viscous forces on the bubble. After measuring the beer's viscosity and density, one can obtain an approximation for the Reynolds number of a rising beer bubble. We see that the rise of a beer bubble in a typical glass occurs at low to moderate Reynolds numbers ($R < 50$).

Although there is no simple solution for the expected drag on a beer bubble, it is instructive to assume that a beer bubble can be modeled as a slowly growing rigid sphere. Surprisingly, the drag on a rigid sphere is not a solved problem. Thus, we must rely on a large body of experimental data that is well known to the fluid dynamics community but perhaps less well known to most beer drinkers. The rates at which spherical objects of different radii and mass move through media of different viscosity and density have been fit to a standard drag curve, which relates the Reynolds number of a rigid sphere flowing in a liquid to the so-called drag coefficient F_d . When one obtains a value for F_d from the standard drag curve and includes it in the previously mentioned differential equation, the resulting first-order differential equation for z can be solved numerically. Our measured values for $z(t)$ agree with this solution when the initial value r_0 of the radius is taken to be 0.0143 cm and the rate of bubble growth νr is taken to be 0.0042 cm/sec, in agreement with the values for r_0 and νr we measured directly from the photograph.

The rigid-sphere model for beer bubble effervescence is an excellent one for the small bubbles seen in a glass of beer. One may wonder whether it is necessary to rely on empirical methods (such as the standard

drag curve) to fit the data. When $z(t)$ is predicted for to analytical approximations to Fd (Stoke's law and Oseen's law), neither reproduces our observations. If the beer bubble had a chance to grow just a little larger, as it would on a journey to the top of a pitcher, then even the rigid-sphere model would be expected to break down. The rigid-sphere model is expected to underestimate the drag on such a rapidly moving bubble.

Foam: More than meets the eye

To understand why a beer bubble would rise more slowly than expected from the rigid-sphere model, we must examine the bubble after it has reached the surface of the beer. At the top of the glass, beer bubbles collect in a foam, called a head, which many beer drinkers will tell you never lasts long enough, while others argue that it lasts too long. For brewers the appearance and staying power of the head are often extremely important. In pure water, bubbles burst almost immediately on reaching the surface, whereas at the beach you will see foamy whitecaps on ocean waves. Whitecaps are caused primarily by the presence of a film of organic matter on the ocean's surface. Some beer manufacturers take the hint from nature and fatten the foam by adding surfactants to their beer. As it turns out, these and naturally occurring surfactants in beer significantly influence the dynamics of beer bubble effervescence. Thus the actual trajectory of a beer bubble is a complex matter.

It has been observed that the presence of even a small amount of surfactant significantly reduces the terminal velocity of an air bubble in water. Surfactants affect the ascent of a bubble by forming a rigid wall around the bubble, eliminating the lubricating effect of the circulation of the gas in the bubble; by causing enhanced boundary-layer separation, larger wakes and earlier vortex shedding; and by reducing the surface tension of the liquid, allowing the bubble to distort more easily from a spherical to an ellipsoidal shape. Not all of these effects operate in the same direction, but the net result is to slow the ascent of the bubble with respect to the prediction of the rigid-sphere model.

No one has quantitatively described the flight of a beer bubble from first principles, but a qualitative picture of the rise of a growing bubble is available. When the bubble is very small it is indeed spherical, but when it reaches a radius of 0.03 cm, it becomes ellipsoidal, with the major axis horizontal. Bubbles in a beer glass are usually so small that this effect does not play an important role. (If they appear ellipsoidal, it is most likely caused by the lensing effect of the glass.) If the radius of the bubble grew to roughly 0.1 cm -- as it would in a "yard" of ale -- the bubble would have reached a critical size at which its radius would begin to oscillate in time. It is believed that such oscillations are driven by the interaction of a bubble with its wake as the wake is shed. The oscillating bubble no longer ascends in a straight line but instead travels in a zigzag or helical path. While the bubble oscillates, its velocity increases very little with increasing radius. The onset of oscillations in bubble flow is accompanied by a sharp increase in the drag on the bubble. For an air bubble in pure water, the terminal velocity of a 1.3 mm bubble is actually greater than that of a 2.0 mm bubble because the 2.0 mm bubble oscillates. If the radius were to approach 1.0 cm -- as it could in, say, a 5 m deep fermenting vessel -- the bubble would deform into a spherical cap, flat on the bottom and rounded on the top. A bubble of this size would be expected to exhibit a Rayleigh-Taylor instability and break apart.

The deformation, oscillation, wandering and ultimate breakup of a rising, rapidly growing bubble make beer bubble dynamics a rich phenomenon, worthy of study in the laboratory as well as in the pub. Well, here's suds in your eye. Bottoms up!