David Alciatore ("Dr. Dave") **ILLUSTRATED PRINCIPLES**

"Squirt – Part II: experimental results"

__Note__: Supporting narrated video (NV) demonstrations, high-speed video (HSV) clips, and technical proofs (TP) can be accessed and viewed online at __billiards.colostate.edu__. The reference numbers used in the article help you locate the resources on the website. If you have a slow or inconvenient Internet connection, you might want to view the resources from a CD-ROM or DVD. See the website for details.

This is the second article in a series dealing with "squirt." So far, we have looked at basic terminology and the physics behind squirt. To refresh your memory, **squirt**, also called **deflection**, refers to the angular change in the initial cue ball (CB) direction due to an off-center hit. In other words, when you use English, the CB doesn't go where you are aiming because of squirt. For more background information, see my August '07 article and refer to **NV 4.13** and **NV A.17**. When using English, it is also important to be aware of the effects of **swerve** (see **NV 4.14** and **NV 7.12**) and **throw** (see **NV 4.15**, **NV 4.16**, **NV A.21**, and my August '06 through July '07 articles). Sometimes, the term "**effective squirt**" is used to refer to the net effect of both squirt and swerve on the shift in the CB position at object ball (OB) impact (see my August '07 article for more information). If you want to refer back to any of my past articles, they are all available on my website (__billiards.colostate.edu__).


normal video

NV 4.13 – Squirt due to high speed English
NV 4.14 – English curve due to an elevated cue
NV 4.15 – Using throw to make a partially blocked shot
NV 4.16 – Over-cutting a cut shot to compensate for throw
NV 7.12 – Small-curve massé shot
NV A.17 – Effective squirt vs. speed
NV A.21 – Bank shot using throw and spin transfer

This month, I want to share the results of some experiments I performed recently to demonstrate if and how much squirt varies with tip offset (English) and shot speed. **Diagram 1** shows the experimental setup used. A template (available in the "Instructor and Student Resources" section of my website) is taped to the table. The template has markings for CB position, lines for tip offset and aiming alignment, and a grid for measuring the amount of squirt over a short distance. Clear transparency film (used on overhead projectors) is taped over the paper template to provide a smoother surface. The film is also sprayed and wiped with silicone spray to further reduce friction. Bob Jewett and I came up with this idea one day on the phone when we were discussing how to reduce the effects of swerve is squirt-measurement experiments. Thanks Bob! Because the measurement is taken over such a short distance and because the friction between the plastic and ball (also sprayed and wiped with silicone) is so small, the effects of swerve are practically non-existent.

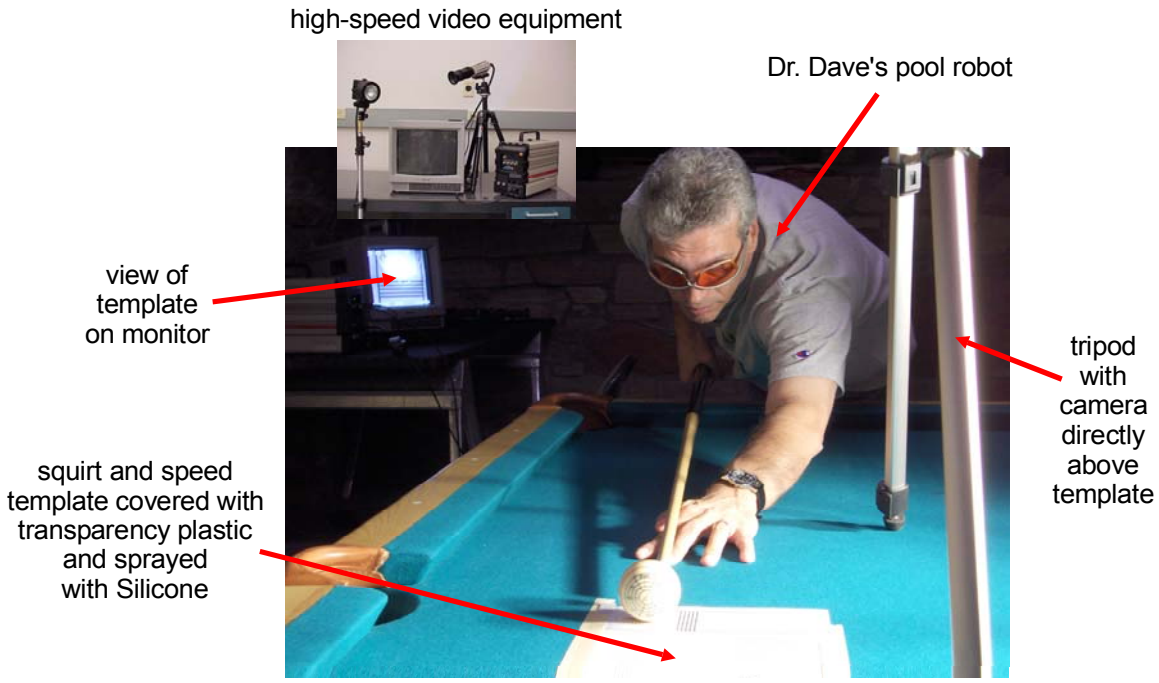

Diagram 1 Experimental setup used to accurately measure speed and squirt

Continuing with Diagram 1, a Jim Rempe CB was used because its many markings help line up the shot and the amount of tip offset consistently. Also, the exact amount of tip offset can easily be measured after a shot by observing where the chalk mark is on the ball relative to the markings. High-speed video equipment (running at 1000 frames/sec) is used to visually see where the CB crosses the squirt measurement grid. The camera is mounted on a tripod directly above the template grid (see the image on the monitor). The high-speed camera requires bright lighting. Two 500W Halogen lamps were used (not shown), hence the need for the sunglasses on the shooting "robot." Sunscreen on the arms is also recommended. The "robot" is Dave Gross, a top regional player with a very repeatable stroke.

For the experiment, shots were taken at three different offsets (small, medium, and large amount of English) with three different speeds (slow, medium, and fast). Three trials were done for each offset and speed for a total of 27 shots. Shots that didn't feel right to the shooter were discarded, and those shots were re-done. The cue stick used was a 21oz Players XIX with a 12.75 mm tip. I chose this cue because it was the largest-squirt cue I had available in my collection, other than my break stick. **Diagram 2** shows the results of the experiment. The plot shows how squirt angle varied with shot speed for the three different tip offsets. Obviously, the amount of squirt increases with the amount of tip offset. This is clear from the large-offset curve being much higher than the small- and medium-offset curves. Notice how the medium- and large- offset curves are very flat, indicating that the amount of squirt does not vary with speed, as many people think (in fact, I used to think this also). Honestly, I can't explain why the small-offset curve has a slight up-trend and the other curves don't. This could imply that swerve might have been a factor. At higher speeds, there would be less swerve and more effective squirt. Because we did the small-offset shots first, maybe the silicone spray was not as plentiful and well distributed on the plastic; although, I did re-apply and wipe before each set of runs. Before I decided to use the silicone spray on the plastic and ball, the amount of effective squirt increased significantly for higher speeds for all offsets, because swerve was a bigger factor for the slower-speed shots.

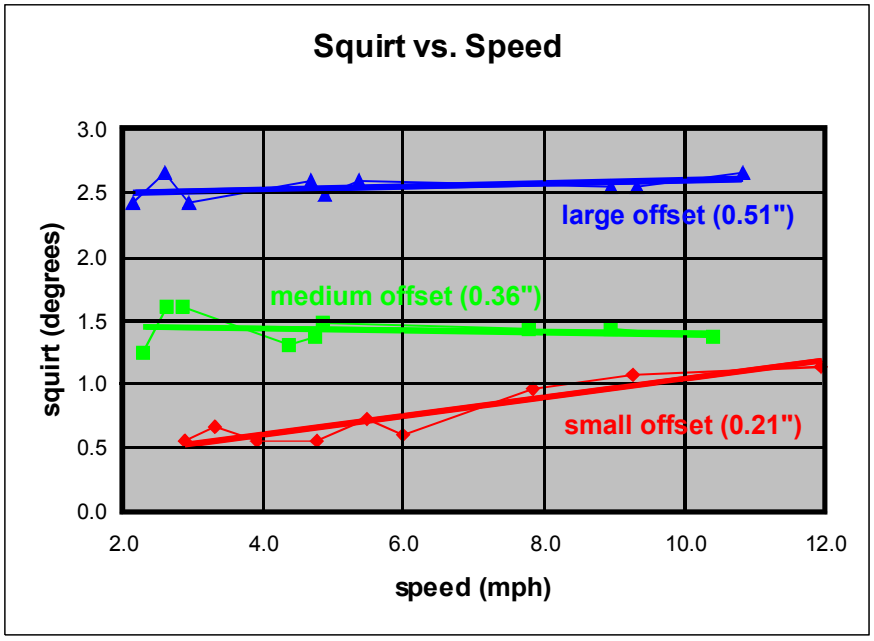

Diagram 2 Squirt vs. speed for different offsets

Another possible explanation for the slight up-trend in the small-offset curve in Diagram 2 is human shooter error. Although, I doubt my "pool robot" introduced any significant error. He is a top regional player and his stroke is very reliable. However, I will reserve judgment until I can run some tests in the future with a mechanical stoking machine that I am currently building. This machine will be capable of a perfectly straight and repeatable stroke at controlled speeds, and the stick will be mounted horizontally over a simulated table so swerve will not be a factor whatsoever. Swerve occurs only with an elevated cue; and at a pool table, the cue stick is always elevated a little to clear the rails. I look forward to using my mechanical "robot" in the future. Until then, I'll need to continue to use the human shown in Diagram 1.

Diagram 3 illustrates how much squirt can affect a shot. The shot on top is for a large tip-offset (about 100% English, at 0.5 inch tip offset) hit with the Players cue mentioned above. The bottom shot is for a Predator Z-shaft for comparison. As shown in Diagram 2, the Players cue had a squirt of about 2.5º for the large tip-offset. We performed similar tests with a Predator Z-shaft and measured a squirt of about 1.8º for the same tip-offset. As you can see in the diagram, the actual final CB position on the right is significantly off from the aiming line target. The squirt and CB deflection are less for the low-squirt cue (about 30% less), but the effect is still significant. For large tip-offset shots, squirt can result in several inches of CB deflection in a long shot. Obviously, one needs to adjust one's aim quite a bit to compensate for this effect (more on this in a future article). I think an important message from Diagram 3 is to think twice before using English on a long shot or with a large cut angle where accuracy is critical.

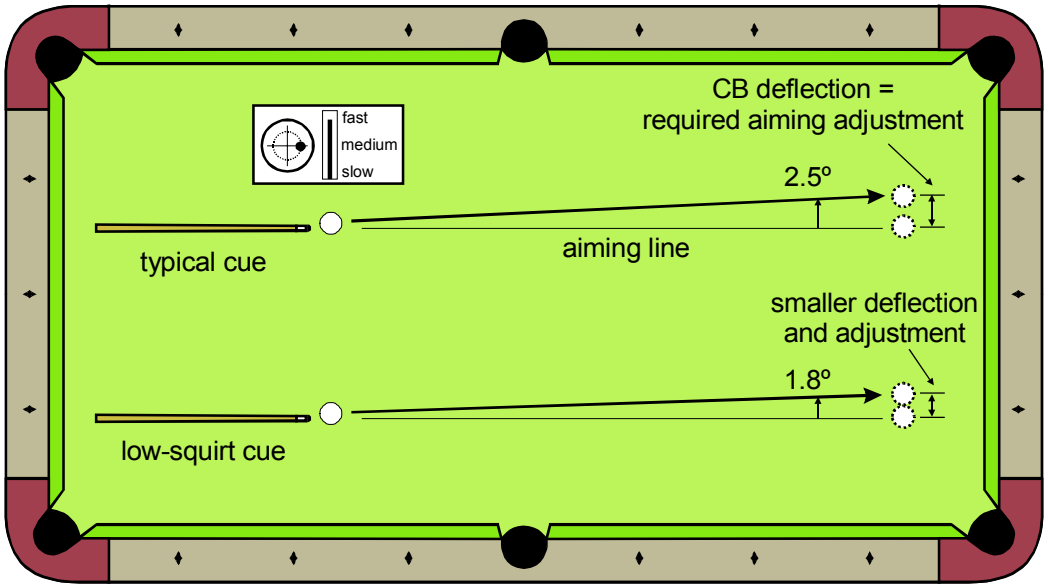

Diagram 3 Squirt for typical and low-squirt cues

Note that the effects of swerve are not shown in Diagram 3. For a fast shot, and with slick cloth and/or a new, clean, polished, and/or silicone-sprayed CB, this is appropriate because there will be very little swerve. However, for slower speed shots under typical playing conditions, swerve would certainly be a significant factor on a long shot like this. With right English, squirt is to the left and swerve would curve the CB back to the right some reducing the effective squirt (CB deflection) at the target. In fact, it is possible for swerve to completely cancel or even reverse the amount of effective squirt for certain speeds and shot distances. In other words, with slow enough speed (and enough cue stick elevation), swerve could cause the CB to curve to the right of the target, instead of to the left (due to squirt alone) as shown in Diagram 3.

I hope you are enjoying and learning from my series on squirt. Next month, we'll look at the effects of follow and draw on squirt and effective squirt. I hope you look forward to rest of the series.

Good luck with your game,
Dr. Dave

PS: I know other authors and I tend to use a lot of terminology (e.g., squirt, throw, cling, stun, tangent line, 30º rule, etc.), and I know not all readers are totally familiar with these terms. If you ever come across a word or phrase you don't fully understand, please refer to the glossary in my book. For convenience, an electronic copy is posted online in the "Instructor and Student Resources" section of my website.

Dr. Dave is a mechanical engineering professor at Colorado State University in Fort Collins, CO. He is also author of the book, DVD, and CD-ROM: "The Illustrated Principles of Pool and Billiards," and the DVD: "High-speed Video Magic."