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

# "Squirt – Part I: introduction"

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***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](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.*

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This is the first article in a series dealing with "squirt." **Squirt**, also called **deflection** or **cue ball deflection**, refers to the angular change in the initial cue ball (CB) direction due to an off-center hit. **Diagram 1** illustrates the effect. When the CB is hit off center, to impart English (sidespin), in addition to the large force in the aiming line direction, there is also a small sideways force that pushes the CB off line. In other words, the CB does not go where you are aiming. The squirt angle is a measure of how much the deflected cue-ball path differs from the aiming-line direction. I prefer the term "squirt" to "deflection," because when talking about a "low-deflection" shaft, things can be confusing. A "low squirt" shaft produces less "CB deflection" than an average shaft; but the end of the cue stick, because it is lighter than normal cues, actually deflects more after impact with the CB (e.g., see **HSV A.109**). So a low-squirt shaft produces *smaller CB deflection*, but it results in *larger cue stick deflection*. That's why I think the term "deflection" can be confusing when discussing cue sticks.

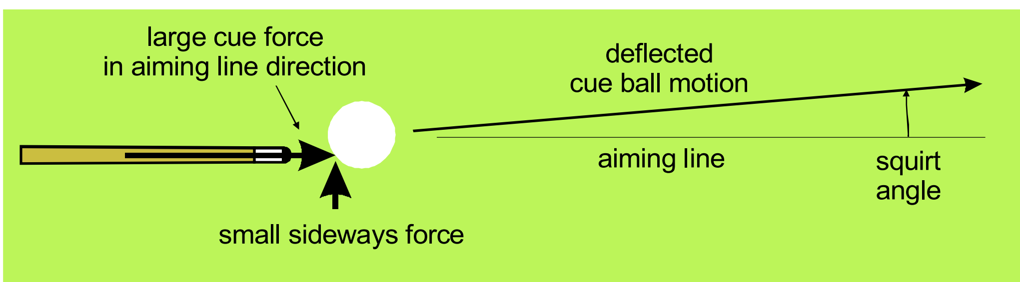
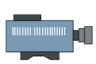



**Diagram 1 Squirt**




**HSV A.109** – English and squirt for a Predator Z shaft at fast speed and increasing offsets

**Diagram 2** visually illustrates the physics behind squirt. The photographs are stills from a high-speed video shot by the Billiard SportKlub Union out of Austria (www.bskunion.at). The footage was shot with a very expensive camera capable of full-color, high-resolution, video at 2000 frames per second. That's over 60 times faster than a normal video camera. The full video can be viewed at **HSV A.76a**. The stills in Diagram 2 are impressive, but you really should view the video online to appreciate the full effect. Still "a" is just before contact. Stills "b" through "e" represent a little less than 0.001 second (one thousandth of a second) during which the tip is in contact with the ball. In still "f" the tip hasn't fully recovered from the compression yet as the CB is separating. Still "g" is after separation. The line and arc appearing in each still mark the initial cue stick and CB positions. Notice how much the cue tip deflects away (down in the diagram) from its original line of action. Also notice how much the cue tip deforms (e.g., see still "d"). Isn't it amazing that the tip can take this much abuse and still return to its original shape, shot after shot? Those leather tips, which haven't changed much in 200 years, are quite resilient.

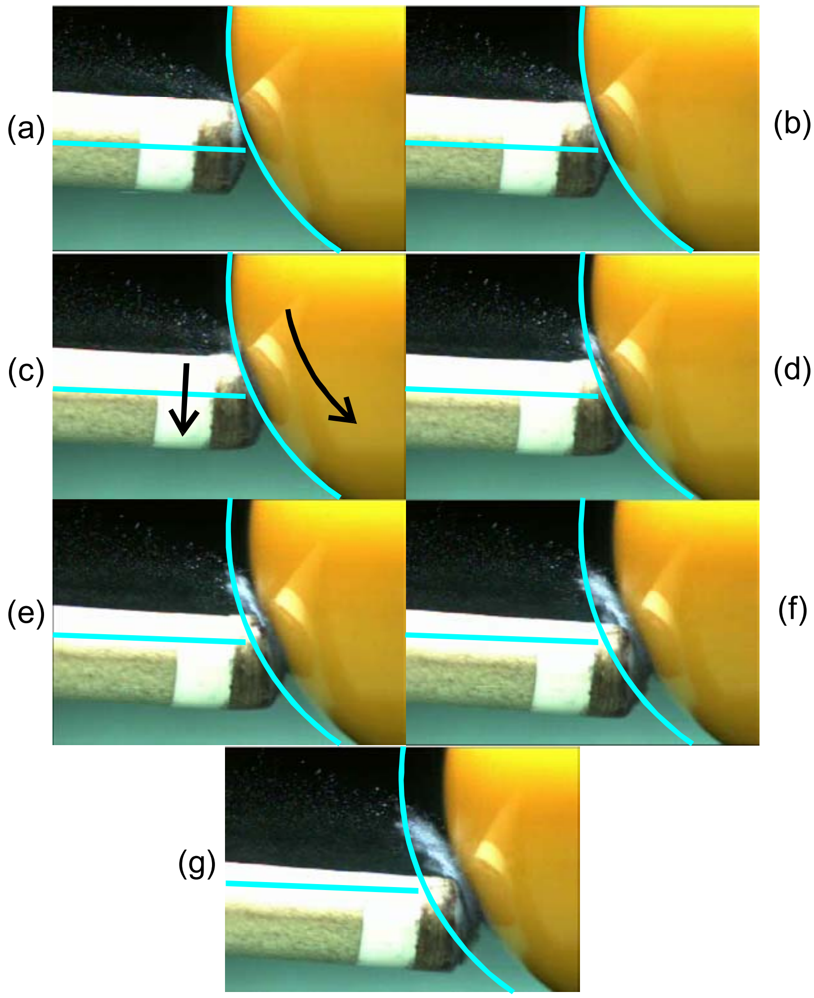



**Diagram 2  High-speed video stills showing cause for squirt**

high-speed video

**HSV A.76a** – close-up of tip during off-center hit

The black arrows in still "c" of Diagram 2 illustrate the effect that causes squirt. While the tip is in contact with the ball, the ball starts rotating. This rotation (counterclockwise in the diagram) pushes the cup tip down a little during contact. Because the end of the shaft has mass, it takes force to move the end of the shaft down as the ball rotates. Isaac Newton said: "for every action, there is an equal and opposite reaction;" therefore, if the tip is being pushed down by the ball, the tip will push back with an equal and opposite force on the ball. This force (see Diagram 1 again) is what causes squirt. Regardless of how good the tip is or how well it is chalked, there will always be sideways motion that will result in squirt. The only way to reduce the amount of squirt is to reduce the amount of shaft end-mass so there is less inertia to support (and create) the sideways force. That's how low-squirt cues work: less end-mass = less sideways force = less squirt.

Another thing to notice in Diagram 2 is the huge cloud of chalk that forms during impact. The tip actually had more chalk than necessary, as evidenced by the trail of chalk particles visible in still "a," even before the tip hits the ball. However, even with a small amount of chalk on the tip, much of the chalk leaves the tip during the shock associate with the collision between the tip and the ball. That's why it is important to chalk before ever shot. That's also why it is important to vacuum your table periodically. All of that abrasive chalk dust settles into the cloth and makes everything (cloth, balls, and slate) wear faster.

When using English, squirt isn't the only effect you need to consider. **Diagram 3** illustrates all of the effects that come into play when using English. When you strike the CB off center, the CB *squirts* away from the aiming line (see **NV 4.13** and **NV A.17**). In other words, it doesn't go where the stick is aiming. The amount of squirt increases with the amount of tip offset from center. The CB also *swerves* (curves) on its way to the OB (see **NV 4.14** and **NV 7.12**). The amount of swerve depends on cue stick elevation, shot speed, and distance between the CB and object ball (OB). Finally, the OB gets *thrown* off the impact line (AKA "line of centers") on its way to the target (see **NV 4.15**, **NV 4.16**, and **NV A.21**). As we saw in my previous series of articles, the amount of throw varies with cut angle, speed, top/bottom spin, and the amount and type of English. If you don't compensate your aim for squirt, swerve, and throw when playing pool (either consciously or sub-consciously), you will never be a great player. Obviously, the amount you need to compensate varies with ball and table conditions, so you also need to be good at adjusting from one set of conditions to another.

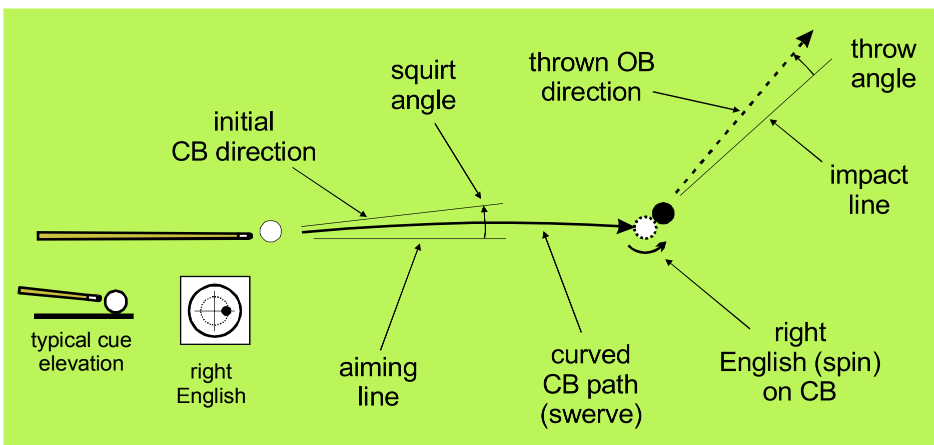



**Diagram 3 All English effects**


**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** – English deflection (squirt) vs. speed
**NV A.21** – Bank shot using throw and spin transfer

Diagram 4 illustrates an important distinction when considering squirt. Swerve tends to cancel the effects of squirt. The swerve effect increases with slower speeds and with higher cue stick elevation. The net effect of both squirt and swerve is what I call "**effective squirt**." This is how much the CB gets shifted on its way to the OB. For some shots with English, if the amount of English, cue stick elevation, speed, and shot distance is right, the effective squirt can actually be zero (i.e., no aim adjustment is required). The effective squirt can also be negative with higher cue stick elevations (e.g., as with massé shots), where swerve is much larger than the squirt effect. I suspect many people really mean “effective squirt” when they use the term “squirt.” Here are some typical statements that make me believe this: “Shot speed affects squirt a lot.” or “Draw shots squirt less than follow shots.” These and other statements apply to “effective squirt” but not to “pure squirt.” We will look at these and other effects more in future months.

People who have performed squirt tests with cue-testing robots (e.g., Predator’s “Iron Willy” and Meucci’s “Myth Destroyer”) also measure “effective squirt,” and not pure squirt. The reason for this is the robots are mounted to pool tables and the cue stick has elevation to clear the rails, and the squirt is measured over a large distance on the table. The problem with this is the results depend on shot speed and the cloth friction. It would be better to build a horizontal cue-stick squirt tester so swerve would not be an issue (i.e., shot speed and cloth friction would not affect the results). Then, “pure squirt” could be measured easily and directly. I am actually in the process of working with some students to design and build such a system. Hopefully, I’ll be able to report some results by the end of the year.

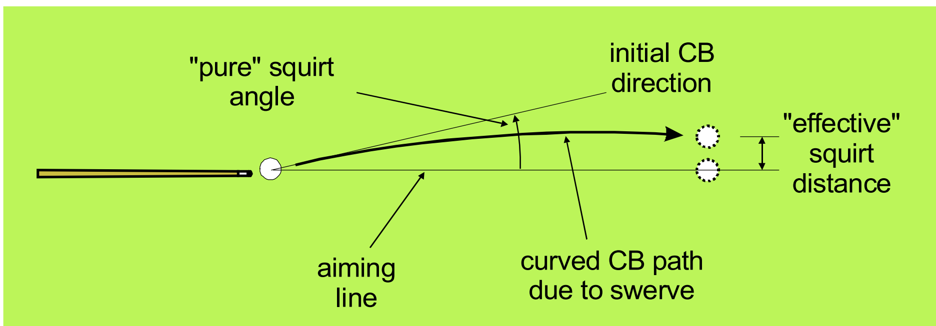



**Diagram 4 Effective squirt**

Over the next few months we will see how “pure squirt” and “effective squirt” vary with speed, follow, draw, and cue stick elevation. We’ll also look at aim compensation techniques used to adjust for squirt. Finally, we’ll look at low-squirt cues and the effects of tip size and shape. 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, impact line, 30 degree 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.

PS: If you want even more background information on squirt, you can refer to Bob Jewett’s 2002 August-October BD articles and Ron Shepard’s 2001 technical paper on the topic. Both of these resources can be access from my website (in the “Physics Resources” section).

*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.”*