Tom's Tech Tips

Ever wonder what REALLY works in paintball? Did that $40 gadget you just bought DO anything different, or did it just make your marker look prettier. Well, Tom Kaye has often asked questions like, how do I make a paintball fly as straight as possible. Can I get more range? Unlike many of us, Tom has the resources to actually TEST his theories in a controlled lab environment.

Barrel Efficiency, Tech Tip #1

Barrels are only there to accelerate the ball from a standstill to 300 fps. In theory they also help with accuracy but that's another post. The ball goes through incredible acceleration on its way down the barrel. The balls acceleration rate is approx. 50,000 feet per second to get to 300 feet per second in 10 inches. The entire barrel travel time is about 6 thousandths of a second and this means the ball is seeing about 1500 G's when its getting pushed out the gun. Although this may sound incredible if someone out there would like to do the math you will see that I'm close.

Air pressure behind the ball is what causes this acceleration to happen. This pressure varies between the different guns but is generally between 50 to 125 pounds per square inch at its peak. The air pressure peaks right when the ball starts moving down the barrel, after that, the ball moving down the barrel creates a bigger chamber so the pressure drops. This is why low pressure guns are a myth, in reality all guns shoot at considerably lower pressure than 200 psi.

Peak pressures above 150 psi tends to break balls down the barrel due to really high acceleration and G forces. If you don't have any way to control the peak pressure behind the ball, the only way you can change it is to go with lower pressure in the air chamber, hence low pressure guns. AGD uses the precise contour of the power tube tip to release air in a controlled manner behind the ball to limit peak pressures to around 60-80 psi..

It is simple to understand that the harder you push something the faster it will accelerate and get up to speed in a shorter distance. So what distance do we have to get the ball up to speed? The effective length of the barrel is from the balls position before it's fired, to the place in the barrel where the pressure gets released, This is usually at the first porting holes or the step in the barrel. Porting is there to release gas pressure!! You are effectively stopping the acceleration at the ports so your 14" barrel that is half full of holes only has an effective length of 7".

Now we understand that we need to limit the peak pressure behind the ball to keep it from blowing up, and that the pressure drops as the ball moves down the barrel. The next question we need to ask is, how far down the barrel does the ball have to go before the pressure gets to low to do anything useful? That answer is 8-10 inches. We know this from looking at the graphs that our gun dyno puts out. If your peak pressure is higher, say over 100 psi you can get away with a shorter barrel, if it's lower then you need a longer barrel. Since AGD is the only gun manufacturer to actually test their pressures behind the ball you might have a hard time getting this info for other guns.

So as far as our guns are concerned, the best efficiency would be had with an 8-10" effective length barrel. Since two piece ported barrels with an effective length of about 5-6" are the rage right now you hear a lot of complaints about gas efficiency. Under some circumstances there is a good reason to use a short effective length barrel. Short barrels cut off the acceleration abruptly by venting and this has the effect of tightening up the shot to shot velocity variation. If you need this at the expense of efficiency then go ahead. Tighter velocity control usually translates into some improvement in accuracy due to better consistency.

So if you want the best of all worlds, limit your peak pressure, let your ball accelerate all it wants, don't follow the crowd and keep asking questions.

Bore Sizing, Tech Tip #2

By popular request I will divulge the inner secrets of bore/paint match (is was 101 degrees out in the field today so I came in early) [Tom was looking for dinosaur bones in Wyoming, Ed.]

Does having a good paint barrel match improve your accuracy??? YES. How does it do it? Very simple, if your gun shoots with a consistent velocity the paintballs will tend to follow the same arc, thereby improving accuracy. It technically is making your gun more consistent which is a better term than accuracy.

Historically there were many theories about paintball barrel matches. First there was the Tippman theory where they used a very large bore barrel and claimed that the air escaped evenly around the ball and it floated down the barrel without touching anything. They claimed this was the "air bearing effect". Next there was the tight barrel theory that said if the ball seals all the way around the shot will be more accurate. Actual testing has proven both these theories false.

Why match paint to barrel? Going back in time the paintballs were much more inconsistent than they are now, in fact now they are really, REALLY round and half the price. Players found that their consistency/accuracy improved when they used certain size barrels. Unfortunately paint is constantly changing size and this requires different barrel id's to work well.

The technique used to research paint/barrel match is simple and doable by anyone. Testing is performed by blowing a thin powder down the barrel to coat the inside. We used to use Desenex Foot Powder that sprayed on dry. Todays Desenex is a different formulation and doesn't make a powder. Once you have coated the barrel you dry fire the gun once to clear out any extra powder. Lastly shoot one paintball out the gun and inspect the inside of the barrel. The powder will be stripped away everywhere the ball touched. This allows you to see exactly what happened to the ball down the barrel.

If the barrel is too big, the ball ricochets back and forth down the tube. We used to say it looked like Zebra stripes in there. Hence big barrels do NOT create an "air bearing". Barrels that are too small scrape most of the powder off and this creates excessive FRICTION. Tighter barrels that were too long were found to slow the balls down due to this friction. In other words, when you

cut these barrels down, velocity went up. Remember the 8-10" acceleration distance, these barrels were 14" long and unported.

The best paint barrel match left two 1/8" wide streaks opposite each other down the barrel. The widest part of a paintball is usually the seam which is also called the equator. With a proper size match only the balls equator touches the barrel snugly on two points. The equator tends not to align itself so the entire seam touches the barrel hence you only get two points touching. So what is happening here that makes this so desirable? We all know paintballs vary in size, this means that there will be slightly more or less friction on the ball depending on how tightly it fits in the barrel. If you use too tight a bore that touches the ball all around, trying to squeeze a bigger ball in greatly increases the friction and changes your velocity. By having the barrel sized to only touch two points, bigger or smaller balls only increase the contact patch a small amount and this gives you better shot to shot CONSISTENCY. To large a bore solves the friction problem but you get back to the ricochet effect.

So this is the story behind proper paint/barrel match. Many of you have commented that the stock barrels seem to work about as good as custom barrels. This is because todays paint is so much more consistent than 10 years ago that the difference between barrels is much diminished. Even the biggest to the smallest barrels don't product that much difference in accuracy IF YOU ONLY COUNT THE SHOTS AT THE SAME VELOCITY. So there you have it, I should mention these studies were done in the early to mid nineties, we have not done any testing lately on two piece barrels etc.

Spinning Paintballs, Tech Tip #3

It was asked in another post what effect do riffled barrels have on spinning a paintball, not drilled holes, actual rifling like in real guns. This is a good question and one that was explored by our research team.

In theory spinning a projectile on the axis of flight adds gyroscopic stability as well as averages out any imperfections in the surface air flow. Paintballs leave a bad turbulence wake behind them that "walks around" the back of the ball as it flies through the air. This is the main cause of a paintballs inaccuracy as the turbulence tail drags the ball around sideways in flight. Spinning the ball should create a tornado like vortex in the back of the ball thereby evening out all the turbulence so the ball is not pulled any particular way.

So great you say lets do it and get more accuracy!! Well if it was possible it would already have been done. The problem is the liquid fill, when you rotate the shell, the liquid tends to stay where it is. The best example of this is a glass of water with ice floating in it, when you rotate the glass the ice stays in the same place (you have all seen it). So if you can grab the ball hard enough to go from 0 to about 10,000 RPM's in 5 thousands of a second (remember TechTip #1?) Yes the shell is spinning but the fill is not. When the ball leaves the barrel the viscosity of the fill slows the shell down but the fill's rotation is speeding up from the shell too, so you get an almost instant reduction of the RPM's out of the barrel. The balls rotation does not come to a complete stop because the shell does impart some spin to the fill. In order to test this properly we actually

developed a gun that spun the barrel, with the ball in it, up to 30,000 RPM's and then shot the ball out.

In this way we knew the ball and the fill were completely up to speed when it left the barrel. We had visions of a spinning barrel paintgun that would make that high speed turbo wine! Unfortunately this didn't improve the accuracy because the ball is still too light.

As a final test we developed a barrel that had three razor edged knife blades running down the length of the bore. Using our plastic paintballs they wedged in the blades perfectly and we spun up the barrel and fired more test rounds. Because the knives would cut the ball we could examine them after the fact to see if they were rotating in the barrel etc. Again unfortunately we saw no improvement in accuracy and gave up.

Based on this data we believe round paintballs are too light and have lousy aerodynamics to expect any more accuracy than what we are currently getting. When the military came to us and wanted a more accurate non lethal system we made a bullet shaped, spin stabilized paintball that far outperformed any equal weight round projectile. Accuracy by volume has been, and will remain, the best way to score eliminations.

How to Test Paintballs and Adjust Breakage, Tech Tip #4

Have you noticed and increase in complaints about paint breakage in the past few months? Do you know that pros with the super tuned guns are dealing with it too? Like to know if it's your gun or your paint? Well read on because this is my fourth installment of Tech Tips designed to inject your brains with knowledge.

Paintballs are made in a 100 year old crude but finely developed process that no one thought would work. The fact that paintballs are as good as they are is really amazing. They are made by pulling two sheets of gelatin, sort of like the Jello stuff, through two pinch rollers. The rollers have holes in them which act like cookie cutters and stamp out the round shape and seal the edges. This is equivalent to taking a piece of round pipe, heating it up the end, press it into a plastic bag laying on the table and trying to seal and cut the plastic at the same time. Now you have to also fill it with goo. We'll try the same thing again but this time you stick a needle between the bag layers, then press the pipe into the bag and seal the needle in the process. Here is the tricky part, you now fill the bag full with goo but don't press hard enough to cut the bag just pinch it closed and seal it. Right when the bag gets completely full you yank out the needle and finish cutting and sealing the bag. Your left with a flexible bag of goo, maybe it leaks maybe it doesn't.

In paintball manufacturing the balls come out of this process all rubbery, flexible and oversize. They really look more like water balloons than paintballs. In order to get them stiff and round they are dried carefully in a tumbling process that takes the moisture out of the gelatin. This is the key point, getting the moisture out. You all know that humidity affects your paint and if you

get it wet it goes to hell. Perhaps you have seen paintballs sitting under a bush at your field that look huge and rubbery, that is the extreme example.

In the past couple years or so it has been fashionable for pros to demand more fragile paint that will always break on impact. This idea of more fragility has spread around the industry and a lot of the paint appears fragile now. I am concerned about this because it is putting a lot of blame on all the guns and pressure on us designers to fix it. Besides that, paint that gets old or is not properly stored tends to get more fragile. So now you can have bad paint being passed off as tournament quality because "that's how they like it"

So how do you know what you have and how do you test it? That is the subject of this tech tip. It is actually a tried and true process called a Bounce Test. We have used it for ten years to determine what type of paint we have and how it will work in the guns. In order for this test to have significance you must do the same thing every time and don't cut it short. Start with 10 paintballs, take one paintball and drop it from about 6 feet and let it hit a hard concrete surface. Catch it on the first bounce, do not let it bounce twice in one drop. Now with the same paintball drop it again from six feet, catch it and repeat until it breaks. Mark down how many bounces it took to break that paintball and then repeat with the other 9 balls. Throw out the high and the low numbers and average the other 8. This gives you the "bounce number" for the paint. Simple but effective. Make sure you use a hard surface not a wood floor etc.

So what does this bounce number tell you? 1-2 bounce paint is super fragile and will break down the barrel in most guns just from the air blast. It will also break in your tubes if you don't pack them tight. 1-2 bounce is pretty worthless paint, you can get it at Wall Mart. 2-3 bounce is considered fragile tourney paint, breaks on people and in the guns too. We are now seeing some field paint at this level. 4-6 bounce paint is good all around and considered fresh. It goes through most guns very reliably but will bounce more often on long shots. 6 and higher used to be considered the best tourney paint in the early 90's because it would go through the guns and never break. Nelson paint was very notable at 8-9 bounces. This paint is hard to find these days but still fun to shoot. Great for big games and when you just want to shoot a lot and not worry about anything. The best thing about high bounce paint is that as it gets older it still works pretty good. 2-3 bounce paint goes to unusable 1-2 bounce pretty fast.

So now that you know what you have, what do you do about it? Well we have a fix for that too. Back to the idea of moisture, by controlling the moisture in the paint shell you can adjust the bounce level but only to a certain extent. If your paint is too fragile you can generally move it up one category by setting the bag on a table, opening it up and placing a standing glass of water inside the bag and closing it back up. Let it sit overnight and your paint should move up one bounce category. If it's too bouncy (not likely lately) then you can leave the bag open over night and unless your in a humid area the paint should get a little more fragile. All of this is true for standard gelatin paintballs, we have NOT tested the new dry paints so we are not sure if the same thing applies. Test it yourself and let us know.

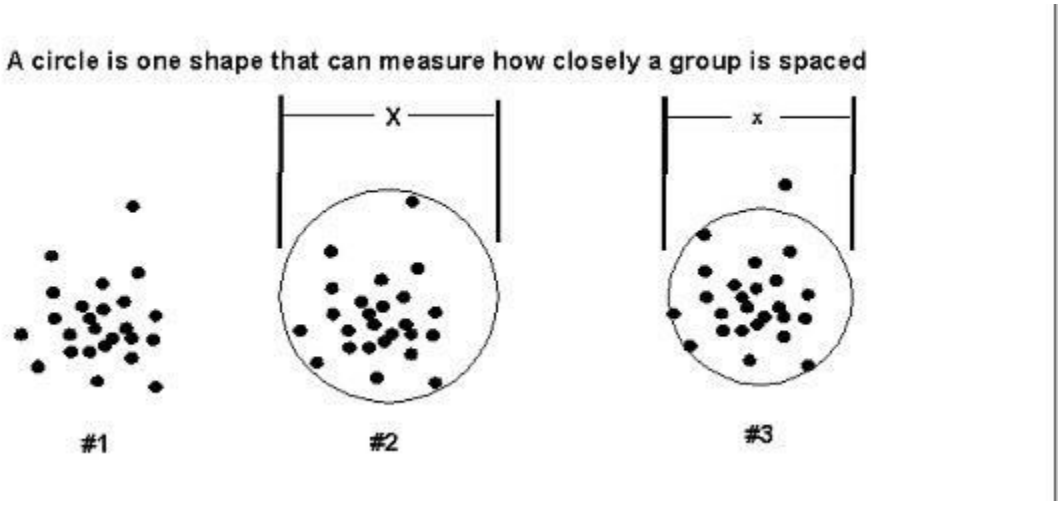
My opinion is that the pendulum has swung too far the other way right now and paint is too fragile. This fragility is masking poorly stored paint and millions of rec players are dealing with broken paint when they shouldn't have too. When doing the bounce test note the variation in how

many bounces it takes to break the ball. If it ranges from 1-8 then it's inconsistent and will give you problems. Good fresh paint consistently breaks between 4-6 bounces and is worth what you pay for it. As with many things in paintball this test is under utilized to diagnose problems. Take it to heart and show your friends, a little knowledge goes a long way. I want to hear about you guys putting this info to use!

Statistics Without Math, Tech Tip #5

In preparation for the analysis of the paintball breakage tests we have to cover the subject of statistics. Many people feel that statistics are unreliable and we have all heard that "you can lie with statistics" but good statistics tells us a lot. For those who are not mathematically inclined, don't worry there are no formulas in this Tech Tip!

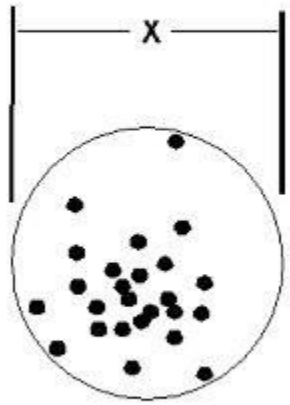
We will examine how to measure the accuracy of a paintball marker even though it might not be very apparent. To do this we have to start with a typical shot grouping as you can see in #1 below.



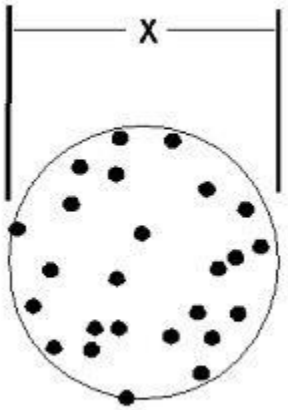
The grouping in #1 is obviously not perfect and they never are, the shots are distributed in a wide area. If you wanted to measure the accuracy of this marker you could use a circular shape around the group as we see in #2 above. We all know that if you measure the diameter of this circular shape it gives you a number that you can use for accuracy. But wait, you say that there is that one "flier" at the top, should you include that? You might say "well that must have been a bad ball so we should leave it out". If we redraw the circle as in #3 our accuracy magically goes up!! Now we have a dilemma, which shape to use and what to include but it doesn't stop there.

If we look at figures #4 and #5 below we see that the same size circular shape can be misleading.

A circle can also be misleading as these two groups show



#4

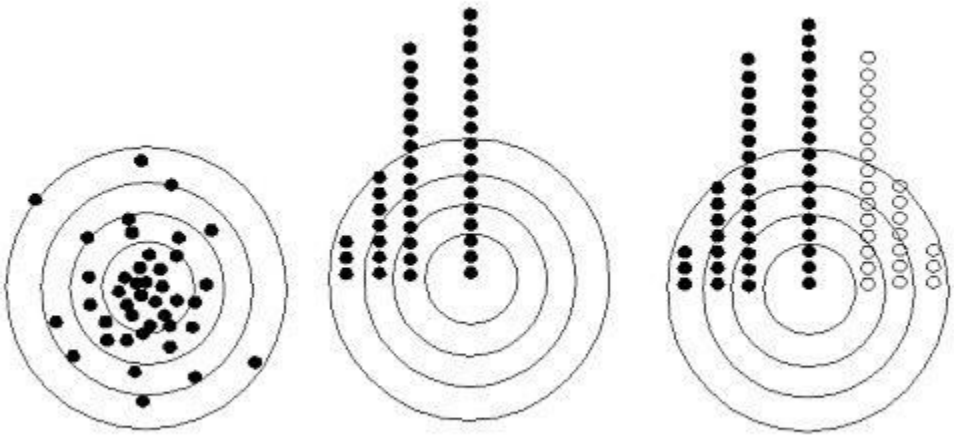


#5

Figure #4 is obviously a tighter more accurate group with one flier, while #5 is worse overall but still fits in the same circle. So now we understand the dilemma, how do we measure these distributions accurately? Scientists face this all the time and fortunately there is a simple way to use another shape to more accurately tell us what we have. It takes a few more steps but they are not that hard.

The first step in statistically analyzing the distribution is to use more circles, as we see in #6 below, to give us some zones to count hits in.

Here we stack up the hits in each zone and mirror the results

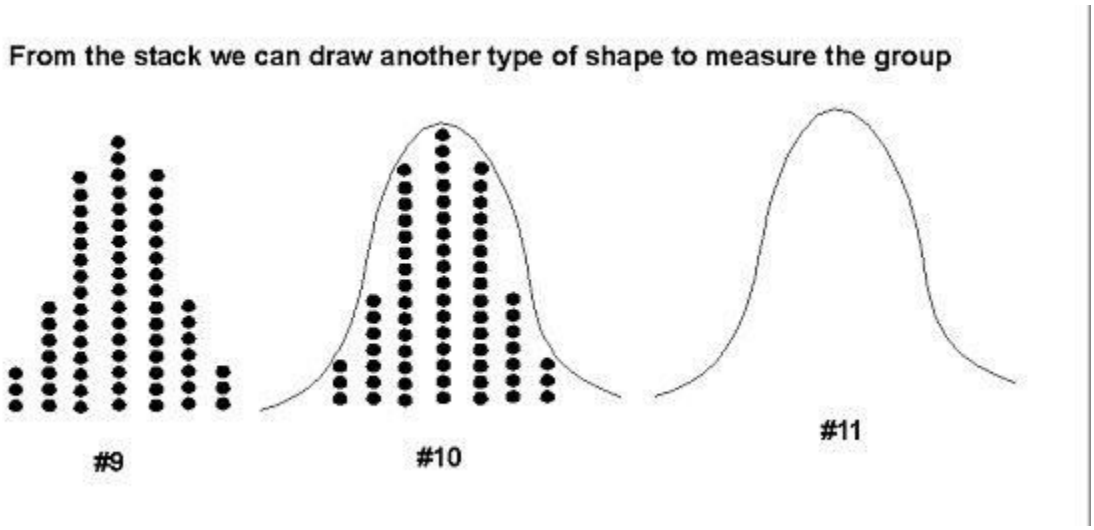


#6 #7 #8

Next in #7 we count the hits in each zone and stack them up. If a hit touches the line we will count it as being in the next zone. In #8 we mirror over the first three columns to the right side so our shape will be easier to see. This is the same data just copied to the other

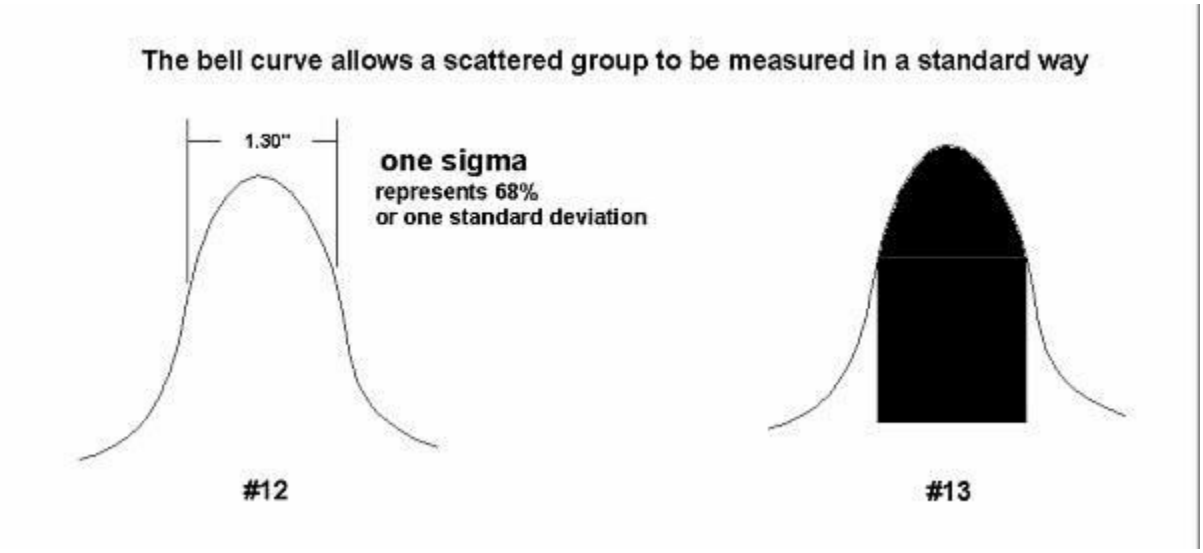
side for clarity.

Now we have a nice stack of hits and can remove the circles as we have done in #9 below.



In #10 we fit our new shape to the stack, look familiar? Sure it is, it's our old friend the Bell Curve!! If you ever suffered through high school math you must have run into this guy. I remember being "graded on a curve" aughh! So now in #11 we have a new shape, the Bell Curve, which has to be fitted to the stack by adjusting it's height and width etc. Programs like Excel do this for you today and just give you the results.

So now that we have our Bell Curve shape how the heck to we measure this weird thing? See #12 below!



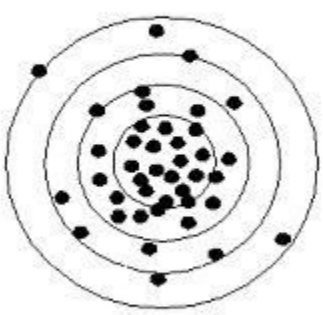
Lets start at the top of the Bell Curve and slide down one side. As we just come off the top, the curve gets steeper and steeper. As we get about half way down the side the curve starts to flatten out. It is at this point, where the curve transitions from getting steeper to getting shallower, that we take our measurement.

We simply measure the width of the curve at that point. This measurement is called, are you ready, a standard deviation! Get it? A "standard way" to measure deviations! Just what we were looking for, yea! Much more sophisticated than a circle, way better than guessing and we got here without math. This measurement is also called one sigma and has it's own special symbol.

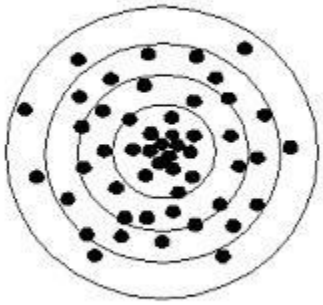
So what does the measure of standard deviation tell you? It means that 68% of the shots were inside this section of the curve. The dark section of #13 represents 68% of all the area under the Bell Curve. It tells you that this marker will put about 2/3rds of its shots in a circle one standard deviation wide. This is how the military measures their accuracy, this is how polls are determined etc. It allows for fliers but doesn't give them a lot of weight.

Now we are ready to compare two shot groups and see what comes out. Look at #14 and #15 below, which one has better accuracy?

Which group has better accuracy? Are you sure?



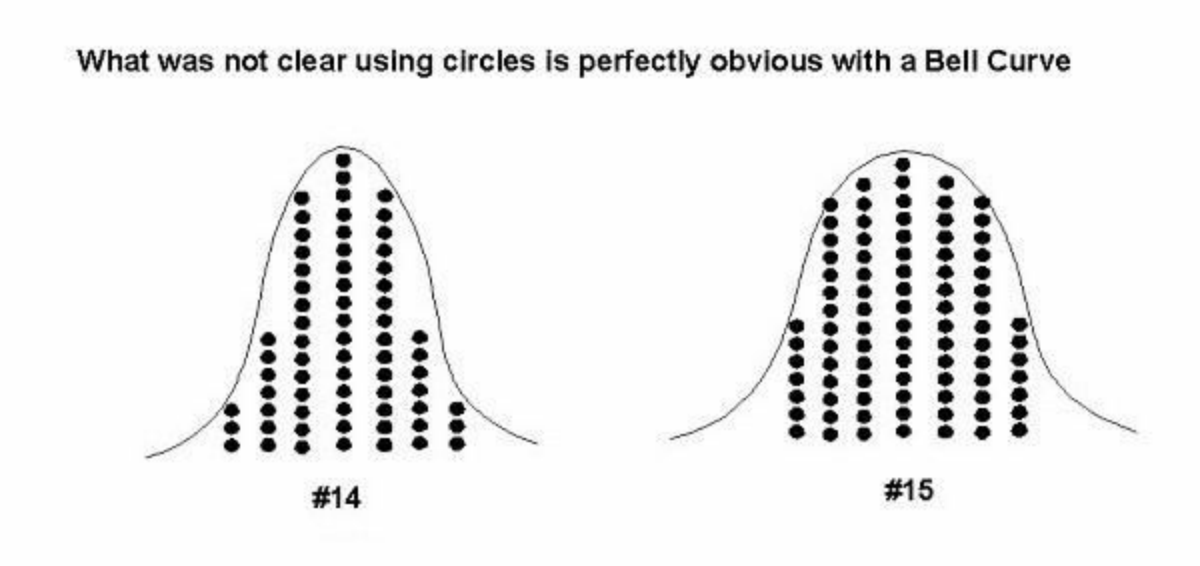
#14



#15

In the two examples above, #14 didn't put that many right in the center but shows a little tighter overall pattern. #15 has a bunch dead center but a wider spread. Two shooters could easily argue that each had the better accuracy than the other. Note that they both fit in the same size circle so that doesn't help.

Below we see the results of a fit to each of the shot groups above.



We see the fruits of our labor as an obvious difference between the standard deviations of the two groups. If we were to take the group and input all the x and y coordinates for each shot into a program like Excel it would just kick out the standard deviation and we would be done. Doing it the long way gives a solid understanding of how we got the measurement.

The one thing we haven't covered is the error factor. In all statistics you get a result, plus or minus X amount. This is the amount that your result could be off if you did the same test again. You wouldn't expect it to be exactly the same but you wouldn't expect it to be way off either. We won't go into all of that here but you now know how to build the curve so errors will make some sense. In order to build an accurate Bell Curve you need a BUNCH of points! If you only had say 10 shots there would be no way you could fit the curve with any accuracy. If you had 1000 shots your curve could be fit very tightly. The moral of the story here is you can't determine accuracy from 5-10 shots. This is why I wanted 40 samples for the paintball test, otherwise the error bars would be so wide they would be meaningless. Sort of like firing one shot, hitting the middle of the target and claiming your marker is perfectly accurate!!

Statistics has shown us the light and made our job easier with less argument. We have learned that a circle is not the best shape to determine accuracy, the Bell Curve part of math really will help you with fun stuff like paintball and most importantly all of this is comprehensible to most anyone. I myself only have a high school math education so I might have missed some details. If I have, some smart people here on AO will be sure to catch it and correct me. If you want to impress on your parents that paintball is more than just a game, tell them in the forum tonight we were discussing a one sigma deviation of a standard distribution based on data taken from two shot groups. Mention you are worried that your error bars were getting out of control due to a lack of input but your Bell Curve should look better after more runs. That might net you some bucks for paint!

On another note Tom Kaye's Tech Tips will be a monthly feature in Action Pursuit Magazine starting in two months. We will be extending our search for truth, justice and the American Way to the rest of the paintball world!

Tom Kaye.