Pellet Testing in Sporting Spring Airguns

By Ian Pellant

The selection of the "best" pellet to use for a particular airgun is an art. A chronograph adds scientific analysis to the artistic process. But unless you perform extensive testing with a good paradigm for evaluation, pellet selection remains more art than science. There are no hard and fast "rules" as to the best pellet for a particular airgun, but there's a plethora of suggestions derived from both experience and imagination that any experienced airgunner is prone to tout as "rules". I'm no different, so what follows are my own findings with a smattering of concepts gleaned from others.

Over the past three years I have spent countless hours with different airguns and a "Shooting Chrony" in the endeavor for definitive rules; just when I think I'm close, some new variable pops up and the goal slips away. Here are some findings for Sporting Spring airguns that may cause a little controversy, but will hopefully offer some insights about lead Diabolo (shuttle cock shape) pellets and rifled barrels. Steel BB's in a smooth bore are something else!

Pellet "Fit"

Spring airguns encompass traditional metal spring and the newer "gas ram" springs. Pneumatics loosely include CO_2, multi-pump and pre-charged compressed air guns. Spring guns are very different to pneumatics. In the spring gun, the air in the compression chamber is violently compressed by the spring driven piston when the trigger is pulled. Pneumatics releases a blast of pre-compressed air or gas behind the pellet, which is a considerably more gentle process than that of the spring gun. Pneumatics have an air release valve; spring guns do not. This is perhaps the most significant difference between spring and pneumatic airguns when it comes to pellet selection because the pellet itself acts as a pressure release valve in the spring gun. When the air pressure behind it builds to a certain point, the pellet begins to move. As the pellet moves in the spring gun the compression volume behind it diminishes by the volume exposed in the barrel. If the pellet moves too soon, the piston pressure behind it will not reach its full potential and energy in the system may be lost.

Pellet "fit" is a combination of several variables. Most notably the skirt diameter of the pellet.

For a .177" caliber airgun, the pellet head is usually 0.177", but may be 0.176" or 0.178" for different styles or brands of pellet. Ideally, the pellet head should be an exact fit in the bore or a little oversize so that the rifling cuts gently into the head. The pellet skirt on the other hand is deliberately oversized. The skirt is intended to be cut by the rifling so that a gas tight seal is produced in the barrel. Skirt diameters typically range from 0.184" to 0.188" for different styles and brands of pellet. There are pellet sizers available that reduce the skirt diameter to a precise and uniform diameter by pushing the pellet through a die. The Beeman "Pell Size" can size pellet skirts to: 0.1780", 0.1785", 0.1790" or 0.1800" for 0.177" caliber, depending upon the die used.

That's a bag load of size variables. Why so many size options? Several reasons:

In spring airguns, the breech of the barrel is reamed out a little to form a chamber that allows the pellet to be inserted so the breech can be closed. Spring airguns may be sensitive to the size of the pellet skirt. My first experiments with pellet sizing were actually inspired by a particular airgun that refused to accept a particular brand of pellet without the "thumb-nail push" or "skirt squish by closing breech" syndrome. Mangling the pellet skirt while forcing it into the gun does not inspire confidence in ones' hopes for accuracy! So a "Pell Size" was purchased and the cat was let out of the sizing bag.

If our rifle has a precise 0.177" bore diameter at the top of the rifling lands, then a pellet with a 0.188" skirt will either fit neatly into the bottom of the rifling lands, or be swaged down a little or a lot as it is forced down the barrel. The pellet skirt fit is most critical to the timing of our spring gun because the spring / piston system provides the force necessary to fit the pellet into the barrel. The tighter the skirt fit, the more force required. The precise instant when the piston has generated enough air pressure to move the pellet will affect the remaining piston travel and ultimate pressure achieved in the air chamber.

For want of a better term, "timing" in a spring gun means the exact instant that the pellet begins to move relative to piston in the air chamber. It is very analogous to "timing" in an internal combustion engine for reasons that may be become clear in a while.

If the pellet head diameter is 0.178", then some energy will be required for the rifling to cut grooves into the head as well as the skirt; this also will affect the timing. The heavier the pellet, the more inertia (resistance to movement) it has, and that too will affect timing.

Why is timing so important? Well... sporting spring airguns burn oil!!!! They are oil burners. Oil will combust in a spring airgun.

This "combustion" behavior of sporting spring airguns is very well documented in the book: "The Airgun from Trigger to Target" by G .V. Cardew and G. M. Cardew, and makes most thought provoking and entertaining reading. Their experiments revealed that up to 45% of the energy yielded in a test gun was derived from combusting oils.

If you have a sporting spring gun, you should notice a slight burnt oil odor just after firing a pellet; or if you can safely look down the bore from the breech of the opened gun, a slight golden haze will usually be seen. Such are evidence of the traces of oil that have been burnt. (A very little oil is necessary for proper combustion. It is usually provided by the piston head wicking traces of oil or grease thrown from the spring in the air chamber behind the piston. NEVER inject any oil into the air chamber in front of the piston unless specifically advised to by the manufacturer (not to be confused with the distributor!!))

"Sporting" spring airguns need to combust. "Match" spring guns generally do not. Match air rifles usually yield less than 6 foot pounds of muzzle energy. Adult sporting spring rifles are intended to yield just under the UK FAC 12 foot pound limit, or non-FAC guns generally in the 20 to 30 foot pound class. They all burn oil. Sporting spring guns are tuned for power; Match guns are not. Match spring guns generally work in the "pop gun" phase (re: Cardew) and are not designed to burn any oil whatsoever. That is why Match guns often use steel piston rings that exclude oil from the air chamber.

Exactly when the oils combust depends upon the volatility of the lubricant, it's mix ratio with the air available and the pressure and temperature exerted upon it. If that sounds a little like a Diesel engine, it is, but with one major difference: the oils in the spring gun are meant to burn, NOT detonate! "Dieseling" in a spring gun is horrifically obvious; the gun fires with the noise of a firearm and sometimes with the smoke of a flintlock! Detonation in a spring gun is to be avoided at all costs; it can cause serious damage to the piston head, spring, and integrity of the gun and may be dangerous for the person holding same! The oil should combust in the transfer port or the breech; if it ignites in the air chamber, detonation may result.

To achieve the correct timing in our sporting spring gun the pellet is all important; it is the only variable besides lubricant that you can play with. Despite "common sense", fitting a more powerful spring to your gun usually does NOT produce more energy because the air is compressed too soon and the pellet is forced to move before the air pressure can reach the correct pressure and temperature for the oils to combust. Often fitting a less powerful spring will yield more energy. Refer to Cardews' experiments for some intriguing details.

Most pneumatic airguns have bolt actions that push the pellet into the barrel. Pneumatics do not burn oil and do not require the pressure relief valve timing properties of pellet fit as do spring air guns. For these reasons, pellet sizing for pneumatics is more concerned with consistent accuracy than energy efficiency. Pellet weight however becomes very important in pneumatics because it will affect the efficiency of energy transfer from the relatively large volume of compressed air and the pellet. The peak air pressure in a spring gun occurs before the pellet moves, whereas in a pneumatic, the peak pressure may not occur until the pellet is some way down the bore. Pneumatics usually exhaust air from the barrel at higher pressure and velocity than do spring airguns, that is why pneumatics are noisier.

Pellet Weight

As already mentioned, the pellet weight affects its inertia. The heavier it is, the more energy is required to get it moving. If the pellet is too light, no matter how tight the initial fit in the bore, it may be too far down the barrel, causing loss of compression pressure for correct combustion to occur in a spring gun, or it may be expelled from the barrel of a pneumatic before the full energy transfer has occurred from the compressed gas.

In a sporting spring rifle of 12 foot pounds muzzle energy or more, it is extremely difficult to propel very light weight pellets efficiently unless they have a very tight fit in the bore. Some innovative composite lightweight pellets have been developed that encase a metal core in a plastic sleeve that both reduces overall weight and increases initial resistance to enable effective combustion in spring guns built to the 12 foot pound limit. Such projectiles can break the "1000 fps barrier" (a marketing goal) with otherwise average power airguns.

Advertised muzzle velocities for airguns mean absolutely nothing unless the pellet weight is also given.

Muzzle Energy

Energy is calculated from the Newtonian equation: $E={}^{1}/_{2}mv^{2}$

That is: Energy equals half the mass times the velocity squared. (Mass is not weight, so real calculations involve acceleration due to Gravity to derive Mass from Weight). Simple physics. It is an "inverse square" relationship which means that is takes 4 times as much energy to accelerate to 2 times the velocity... 16 times the energy for 4 times the velocity and so on. In simple terms a gun pushing a projectile at 1000fps is 4 times more powerful than a gun firing the same projectile at 500fps.

Muzzle energy is the only reliable guide to the power of an airgun.

Evaluating Pellets

The great variety of pellet brands and styles are almost all of different design weights. Except for a few "standards" like 7.9gr for 0.177" where several different brands and styles are available.

To evaluate how efficiently a particular airgun propels a pellet, muzzle energy is the only metric.

The combination of pellet weight, head and skirt sizes, skirt "expandability" resulting from material thickness and hardness, and the diameter and cleanliness of the bore will all affect inertia and the critical timing of spring airguns. There are just too many variables to predict results without actually testing a variety of pellets in your particular gun.

Accuracy is a different subject. It does little good if the most energy efficient pellet in your gun leaves the barrel badly deformed or traveling too fast for it to be stable. "Shoot and see" is the only metric for accuracy.

For a spring airgun, the maximum energy available is fixed. Pneumatics are somewhat more variable, either by the number of pumps given, or the temperature of the CO_2 or by the air pressure left in the reservoir. If you can stabilize the available power then you can compare various pellets to see how well they utilize that energy.

In my "Airgun" software (available for download), I developed the concept of energy efficiency by calculating the average muzzle energy from measured shot velocity strings and then assigning 100% to the highest result and rating all other results to that value. A chronograph is a must for this analysis.

Testing Pellets: a Case Study, the BSA Superstar in 0.177" Caliber

One of the secrets of airgun manufacture is how European guns built to the 12 foot pound FAC (Fire Arms Certificate) limit can have a non-FAC variant exported to the US, producing 14 to 16 foot pounds. The secret may lie in transfer port size, spring selection or lubrication or simple chance of manufacture. It may remain a secret to prevent European airgun owners tuning their guns to illegal power levels! Anyway, the BSA range of air rifles imported to the US produce up to 15 or so foot pounds, my Superstar is one such rifle.

The following table is a summary of results from the Superstar shooting a variety of pellets:

Pellet	Sized	Average Velocity Feet per Second	Average Energy Foot Pounds	Energy Efficiency
6.90 gr RWS Hobby	No	936.81	13.45	93.14%
6.90 gr RWS Hobby	0.1800	933.74	13.36	92.52%
7.10 gr Beeman Silver Bear	No	956.94	14.44	100.00%
7.10 gr Beeman Silver Bear	0.1800	956.04	14.41	99.79%
7.40 gr RWS Super H Hollow Point	No	935.65	14.39	99.65%
7.40 gr RWS Super H Hollow Point	0.1785	910.73	13.63	94.39%
7.40 gr RWS Super H Hollow Point	0.1800	918.04	13.85	95.91%
7.70 gr Beeman Laser Sport	No	885.55	13.41	92.87%

8.80 gr Beeman Crow Magnum	No	858.55	14.41	99.79%
8.80 gr Beeman Crow Magnum	0.1800	853.04	14.22	98.48%
10.50 gr Crosman Premier	No	734.13	12.57	87.05%

From this series, you can readily see that the Beeman Silver Bear pellets yielded the highest energy when they were unsized. The Crow Magnums come a close second. Beeman list the head diameter of the Silver Bear pellets at 0.177" and the Crow Magnums at 0.178". This may contribute to the slightly less energy yield because energy was expended cutting the larger head into the rifling and higher frictional loss as the Crow Magnums pass down the barrel.

In all test cases, sizing the pellets caused an energy loss.

The big disappointment in the test group were Crosman Premiers in 10.5gr. These are about the heaviest 0.177" pellet available and are most favored by Field Target shooters; possibly shooting pre-charged pneumatic guns. The Superstar has a noticeable spring "twang" when shooting the Premiers. This implies that the Premiers are a looser fit than other pellets in my gun and do not offer sufficient inertia for correct timing. The energy loss is far too great to be ignored; obviously they do not suit my gun very well.

Unfortunately I do not have a reliable means to measure the head diameter of pellets, but the relative skirt diameter can be approximately deduced by forcing pellets through a sizing die. Another simple trick gleaned from "The Airgun from Trigger to Target" is to get a ball-point pen with a clear outer case, remove the ink innards and drop pellets into the outer case - the further they drop in the tube, the smaller diameter is the pellet.

Here are my comparative findings:

	Beeman Silver Bear	**Crosman Premier**
Weight	7.10 gr	10.5 gr
Skirt Diameter	0.187"	Smaller
Head Diameter	0.177"	Visibly smaller.
Skirt Characteristics	Thin, long, flexible cone. Able to expand into the bore.	Thicker, stiff, truncated cone. Limited ability to expand into the bore.
Head Characteristics	Semi-wadcutter hollow point. Distinct ring to grip rifling. Ring easily cut by rifling.	Semi-circular dome. No ring. Rifling must cut into dome head if diameter too large.

As in all things, perhaps the Premiers work well in other BSA rifles, but not in mine. My speculation is that the skirt on the Premiers is too thick and stiff to rapidly expand into the breech in a spring gun. The head also must either perfectly match the bore diameter, or be loose; there is no soft contact edge for the rifling to cut into if the head is larger than the bore. Premiers are probably designed primarily for pneumatics, not spring guns, which is not too surprising considering that Crosman / Benjamin Sheridan are predominantly manufacturers of pneumatics.

The test results as a whole, without including the Beeman Crow Magnums, would perhaps indicate that the lighter pellets are a better choice for a gun of the Superstars' power range. But that is not necessarily true. I have not yet tested 11.50gr Beeman Silver Arrow pellets....

The heaviest 0.177" pellets are lighter than most 0.22" pellets. If your airgun comes in a larger caliber than 0.177", then do not be afraid of using the heaviest 0.177" pellets you can find.

Larger calibers are more energy efficient than smaller calibers in airguns. The ratio of sectional area to circumference is: D / 4 (diameter divided by 4); that computes to: 0.04425 for 0.177" and 0.055 for 0.22". There is more surface area to push against compared to the frictional contact as the caliber increases; hence energy efficiency increases with caliber.

My BSA Supersport in 0.22" caliber yields 15.35 foot pound with 12.5gr Beeman Laser pellets but only 14.24 foot pounds with 11.90gr RWS Hobby's. Then again it produces 14.47 foot pounds with 14.00gr RWS Superpoint's while most other pellets yield between 14.24 and 14.47 foot pounds. Laser's stand out from the crowd!

The Supersport really likes Beeman Laser pellets, yielding 8% to 12% more energy than most other pellets tested. Initial results for the Laser's were even more outstanding when I calculated with the catalog weight of 13.36gr. Too outstanding a result of 16.41 foot pounds, so I got suspicious and weighed the pellets, to find an average of 12.50gr (that brought the energy down a bit!)... Still can't explain it though. A gun that would have rated at 14.4 foot pounds hits highs of 15.64 foot pounds with just one particular brand of pellet. Amazing!

Synopsis

So, there is no hard and fast rule about which pellet will work best in a particular airgun. You must shoot a sample of different brands and types, measure the velocity and calculate the energy.

Without shooting through a chronograph you may never know just how "good" some pellets are. But, if your gun has a noticeable spring "twang" and harsh recoil, then it just may be loose pellets... try a different brand as soon as possible. If the gun shoots quieter it didn't like the first brand.

Better buy a chronograph (or beg or borrow one), if you really want to find what's 'best" in pellets for your airgun.

My "rules" / suggestions for selecting pellets for a magnum spring airgun are:

- Don't use cheap, poorly formed and sized pellets - they are a false economy!
- Don't use pellets that are a loose fit for your gun - they can cause premature piston and spring failure!
- If your new spring gun has harsh and noisy recoil, you may have a pellet fit problem. Try some other brand of pellet and do some chronograph testing before blaming the gun or it's lubrication.
- Pellets that perform well in pneumatics may not perform well in spring guns; whereas pellets that perform well in spring guns may perform equally well in bolt action pneumatics.

- Sizing pellets for magnum spring airguns generally may cause energy loss and is not recommended; whereas sizing for spring pistols and match spring guns may yield more energy and consistency.
- Pellets that work well in a spring pistol may not work well in a spring rifle, and vice versa.
- Tend towards the heavier pellets in 0.177" for outdoor use (Field Target and Hunting); mid weight pellets for indoor and calm outdoor paper punching.
- Be careful when testing ultra light pellets in a very high powered spring airgun - they may be inefficient, or worse yet, not offer sufficient inertia to cushion the piston, you may damage your gun.
- Test a variety of brands and styles until you find what works well with your airgun and terminal ballistic needs. Pellet head design plays a large part in energy transfer to the target. High energy does not mean high accuracy. A wide variation in shot string velocities will yield inconsistent energy and poor accuracy.
- Buy a good selection of pellets and test, test, test!

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