A Pre-charged Pneumatic and Co2 Primer

Though pre-charged pneumatic and Co2 guns are pretty simple contraptions, a basic grasp of the physics involved with the two operating systems goes a long way towards getting the most out of these air and gas gun designs. The different physical properties of the two compressed mediums instill profound differences in their characteristics as fuels for the launching of projectiles. Your author will attempt to endure an extreme aversion to technicality long enough to address persistent misinformation about compressed air and carbon dioxide gas operation and performance.

Pre-charged pneumatics and Co2 guns are of very similar design, but with valve and hammer spring tensions adjusted for the different chamber pressures at which the two propellants operate. Contemporary pre-charged pneumatic guns typically operate at pressures of 2,000 to 3,000 PSI, as opposed to typical Co2 pressures of 600 to 1,200 PSI.

Co2 guns exploit the fact that liquid carbon dioxide trapped in a sealed chamber is in a state of reversion back to compressed gas; or perhaps more accurately, gaseous vapor. Co2 chamber pressures also relate directly to the temperature of the gun, which is affected not only by ambient temperature, but also the refrigeration effect of shooting the gun. However, given a constant temperature, the chamber-pressure (that drives the projectile) remains fairly consistent while there remains liquid Co2 in the chamber. Chamber pressure then falls rapidly as liquid Co2 becomes depleted.

The L D custom Crosman is a temperature-tolerant Co2 pistol of excellent power and accuracy.

Any size chamber charged with liquid carbon dioxide returns many more shots than if charged with compressed air. This quality allows relatively high shot counts from relatively small chambers; a characteristic that makes compact Co2 guns possible.

Since Co2 gun operating pressure and muzzle velocity varies significantly with operating temperatures, temperature sensitivity is the Achilles heel of Co2 guns. A difference of only ten degrees Fahrenheit noticeably affects pellet velocity and point of impact. A 20 to 40 degree temperature variable wreaks absolute havoc on trajectories. This is why Co2 guns have largely fallen out of favor for serious competition.

Though much more resistant to weather-related ills, pre-charged pneumatic guns are not affliction-free. Compressed air in a sealed chamber maintains consistent pressure only as long as no air escapes. In other words, only until the gun is <u>shot</u>! So if chamber pressure falls *with each shot*, how is it that PCP's display any velocity consistency whatsoever? This is where the going gets a bit technical.

So as to not over-complicate matters any more than necessary, this discussion will concentrate on unregulated PCP's. Regulated guns are subject matter for another article altogether.

As chamber pressure falls with every shot of an unregulated PCP, there is less pressure against the exhaust valve holding it closed. Consequently, as chamber pressure falls, the force of the hammer-blow opens the exhaust valve slightly longer in stroke and/or duration, allowing a greater *volume* of air to escape to drive the pellet; providentially offsetting the slightly lower *pressure* of air released. Since a combination of pressure *and* volume drives the pellet, this lower-pressure/higher-volume of air exhausted with each shot averages out to relatively consistent pellet velocities over a certain *power-band* of worthwhile shots per charge. At some point chamber pressure drops low enough that the hammer-blow is opening the valve as much as it can open, after which pressure *and* volume of air decreases with each shot and velocity starts a rapid decline.

Perhaps counter-intuitively, excessive chamber pressure actually results in reduced velocity; a situation commonly referred to as 'valve-lock'. Too-high chamber pressure exerts so much pressure against the valve that the hammer blow cannot open the valve enough to propel the pellet to optimum velocity. Excessive chamber pressure can indeed lock the valve (completely) from opening from the force of the hammer impact. However, for our purposes the term 'valve-lock' is used to describe the condition where velocity suffers as chamber pressure impedes the hammer adequately open the valve.

Which brings us to the next pertinent subject- *'bell-curve power-band'*.

We now know that a combination of pressure and volume drives the pellet. Consequently PCP's can return fairly consistent velocities over a certain range of chamber pressure because more volume of air is expelled as the pressure of that air falls with each shot. Therefore, in order to maximize the number of acceptable shots per charge possible with any given pre-charged pneumatic, it is important to discover at what fill pressure the gun starts exhibiting symptoms of valve-lock. But before doing so, it is helpful to decide how much velocity extreme-spread one considers acceptable.

For instance, let's say you can live with a velocity extreme-spread of 30 feet-per-second. Assuming you know the recommended charge pressure of the gun, charge it to a pressure about 300-400 PSI <u>less</u> than recommended and chronograph the velocity over several shots. That fill pressure should produce near peak velocity, an important first step in discovering optimum charge pressure. Within five to ten shots you should see a pattern developing of some kind; either velocities are rising, falling, or remaining pretty static. Since you are searching for the peak velocity, if velocities are rising or remaining constant, continue shooting until velocity begins falling for several shots. Record the <u>peak</u> velocities achieved, and re-charge the gun to a pressure 100 PSI higher than before. **Continue chronographing and re-charging the gun to higher pressures until you discover the fill-pressure that returns velocities 30 feet-per-second <u>less</u> than peak velocity.** That is the <u>optimum</u> fill pressure. However, **never fill a gun to more than 10% higher pressure than manufacturer recommendations.**

Charge the gun to its sweet-spot fill-pressure, then chronograph and record each shot while velocities climb, level off, and fall again to a point 30 FPS <u>below</u> peak velocity. At that point you've found the optimum fill-pressure to return an optimum 'bell-curve' power-band with a velocity extreme-spread of the desired 30 feet-per-second. The goal is to eke-out the maximum number of useful shots by charging to an ideal pressure (of slight valve-lock) that produces 30 FPS less than peak velocity, and shooting until velocity peaks and drops again to 30 FPS below peak velocity. That is the bell-curve. Quite likely, optimum fill-pressure will not be exactly that recommended by the manufacturer. Just as likely, you will enjoy a higher shot-count per charge than if operating at the manufacturer's exact recommended fill pressure.

Now, after all that techno-babble… I mean 'fun', understand that any change in hammer-spring or valve-spring tension alters the mechanical dynamics; hence changing the sweet-spot fill-pressure and bell-curve power-band. Even if the results achieved were not satisfactory, we have at least quantified the gun's performance with a reference point from which to proceed.

This conjures two questions. What happens when we change hammer or valve-spring tension(s), and how do we tune for desired performance? ***Thankfully***, both questions can be answered with just a little more information.

A stronger or weaker hammer-spring respectively increases or decreases the impact energy of the hammer against the valve, allowing longer or shorter opening of the valve, resulting in more or less pressure and volume of air expended to drive the pellet to higher or lower velocities. Of course any change in the valve spring affects the pressure holding the valve closed and the hammers ability to open the valve against said back-pressure. Side-effects of any change in either hammer or valve spring tension are changes in fill-pressure, bell-curve power-band and number of shots per charge.

To summarize the effects of changes in valve or hammer-spring tension- stronger hammer-spring or lighter valve-spring tensions produce increases in velocity and fill pressure, and vice-versa. BOOM… there it is!

That bit of information allows tuning of pre-charged pneumatics for ideals in velocity, fill pressure or power-band. As these three factors inter-relate and must abide by the laws of physics, in most cases the best we can hope to achieve is the ideal in one of the three areas; perhaps also with positive effects on one or both other areas.

Much of the information presented above also applies to Co2 powered guns; however we have little control over chamber pressure beyond obtaining an optimum Co2 charge. To a point, gas-gun muzzle velocities increase as temperatures rise. However, as most Co2 guns are designed to operate at typical chamber pressures of 600-1,200 PSI, it is possible to experience valve-lock in hot temperatures as chamber pressures increase to as much as 1,500 PSI or more. This situation is more common with bulk-fill guns filled to maximum charge density, but also occurs in cartridge guns (especially those of meager power). Powerful Co2 guns are less prone to exhibiting symptoms of valve-lock in extreme heat than guns of moderate power. In fact, a heat-temperamental Co2 gun can be made less so through installation of a stronger hammer spring and/or lighter valve spring.

Since most compressed air and Co2 guns' hammer-springs are somewhat easily accessed, much tuning can be accomplished pretty easily with changes in hammer-spring tension. Delving a bit deeper into the innards, one can also access the valve-spring to experiment with balancing the interaction between the hammer and valve springs. More ambitious tuning can be accomplished by smoothing contours, angles and passageways between the air chamber and pellet chamber, much as an internal-combustion engine tuner ports and polishes a cylinder head for better flow.

Though PCP and Co2 gun tuning is pretty simple stuff, as in many seemingly simple endeavors, the devil resides in the details. While much can be accomplished with basic hand tools, the most necessary tools for airgun tuning are a chronograph and heapin' helpin's of patience and persistence. In any search for the ideal performance envelope, it is not unusual to disassemble and reassemble the piece half a dozen to a dozen times, testing for performance each time.

Some of the author's more enlightening air and Co2 gun tuning odysseys are described in the foot-notes for the Galway Fieldmaster, Shin Sung Careers and

Sportsman QB77 sections of the velocities testing chronicled elsewhere in this book. Ultimately successful, those particular trials and tribulations were excellent, first-hand learning experiences. Crash courses in airgun tuning, you might say.

Trials by fire, I might say.

Virtue of its power-wheel and accessible hammer spring, the Sumatra is a one-gun physics lab.