<u>Chronograph's</u> *(without tears) by David Moore*

Following a number of protests and challenges at recent National and State competitions, it was time to prove or bust the myths of chronographs.

HOW IT WORKS So how does a chronograph work. A chronograph contains an extremely high-speed crystal oscillator or clock that starts running the instant you turn the chronograph on. The clock acts like a stopwatch that is switched on and off by your bullet passing over the photo electric cells..

Two light (or infrared) photo sensitive screens or cells are set a known distance apart in front of the shooter. As the bullet passes over the first cell, the shadow or momentary change in light level starts the clock counting. It continues counting until the bullet then passes over the second screen and this signals the clock to stop.

Typically a chronograph clocks 'counts' at about 4 mhz or 0.25 microseconds for each pulse. That is pretty fast, but then so are our bullets. Once we know the time of travel (number of pulses) and the distance the screens are apart, the computer in the chronograph can easily calculate and display the exact speed of your bullet.

On most chronographs this can be displayed as either feet (FPS) or meters per second (MPS). The computer can also display a number of other data results for multiple shots strings such as Highest, Lowest and Average velocity, Extreme Spread, Power Factor and Standard Deviation.

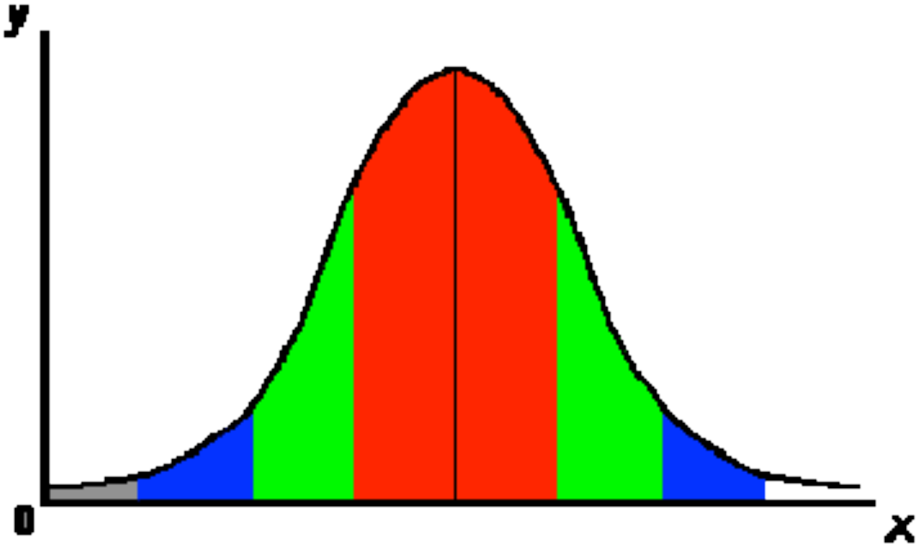
DATA A string is a series of shots (it can be 2 or 200 or any number in between) and for each string a variety of different data can be derived:-

High Velocity - the fastest shot in the string
Low Velocity - the slowest shot in the string
Average (Mean) Velocity - the average speed of all shots combined
Extreme Spread - the difference between the fastest and slowest
Standard Deviation - a measure of how close each shot's velocity will be to the "average" shot

$$Sd = \left[\left(\sum V^2 - n.Av^2\right) \div (n-1)\right]^{1/2}$$

Power Factor – bullet velocity (FPS) multiplied by bullet weight (Grains). This requires the bullet weight to be entered maually

STANDARD DEVIATION Is a measure of how close each shot's velocity will be to the "average" shot. In static's, 68% of all things we measure falls between one standard deviation above or below average, 95.4% falls between two Standard Deviations above and below the average, and 99.7% falls between three Standard Deviations above and below the average]. Thus, Standard Deviation is a universal method in statistics and measurement for dealing with and interpreting data.



For example, if the bullets are traveling at an average velocity of 900 feet per second, and there is a Standard Deviation of 20, then 68% of the shots you fire will fall between 880 and 920 fps, and 95.4% will fall between 860 and 940 fps. Nearly all of them (99.7%) will fall between 840 and 960 fps.
Standard Deviation is the most important information your chronograph can give you and it is useful to understand the reason for this. It is a measure of how consistent your ammunition is and reflects on the quality of your reloading.
At least ten (10) shots are required to obtain a reliable average and Standard Deviation. Fewer shots (such as 3 or 5) are typically "small samples", and are considered unreliable when measuring anything variable.

ACCURACY – CERTIFIED or NOT

The spread between the existing brands of chronographs on the market today is approx. 8.0%. This has a lot to do with the quality of the sensors used and the distance in which the sensors are spaced apart.
The expected accuracy of the clock circuit is very high (better then 99.8 %) and can be certified. People claim very high accuracy with a single shot or reading but you cannot prove it.
The problem error caused by the sky screens spacing and the cone angle of the lens can be greatly reduced by increasing the screen spacing.

	1 FT	**2 FT**	**4 FT**	**8 FT**
500 FPS	24 fps	12 fps	5 fps	2 fps
1000 FPS	43 fps	22 fps	11 fps	5 fps

Typical Errors at Different Screen Spacing

Minimum spacing of 1 foot is *not desirable;* minimum spacing of 2 feet is *recommended,* Spacing of 4 feet is *suggested* for competition.
Most manufactures have a tolerance of about 4% for their error checking circuits (sometimes called Proof channels), which flash or alert you of bad shots or measurements in a string.
And if you put two or even three chronograph inline the typical error is less than 4%.
Although, some small chronographs have been seen to have wild errors in excess of 50%.
So how do we prove a chronograph for a competition?
A simple way is to put two chronographs inline and fire a series of shots. If the results agree within 4%, then you can assume the chronographs are correct, and you should use the higher reading one for the competition. If during the competition the chronograph is challenged or damaged, the other is available for cross checking.
If they do not agree, then you need a third chronograph to determine which is the faulty one, and use the two that tend to agree. Any pistol can be fired over them for the test, as you are

only looking at the differences between readings. An Air pistol will give very constant velocities for comparison of results.

CHRONOGRAPH RESULTS, ERRORS and VARIABLES

1. Temperature, altitude, & the effects these have on different powders. – As a general rule, in cold weather powders burn more slowly and will produce lower velocities than they will at higher temperatures. Loads developed which are near maximum velocity during cold weather may produce dangerously high pressures and be unsafe during hot weather.
2. Temperature of the barrel and the ammunition itself. a cold barrel will produce different results from a very hot one. The same with the ammunition.
3. Different altitudes may also affect velocity. This is also true with flying, velocities can vary for up to three days after air travel.
4. Battery – A good power supply is needed, usually a fresh alkaline battery. Low voltage will give poor or no results. Alkaline batteries hold the voltage better the carbon batteries.
5. Lighting - MUST be balanced on both sensors. If the sun changes position, you must maintain a balanced condition on both sensors. Whether in bright sunlight (using the top screens) or on shady days (in which the top screen is optional), it is critical to maintain a balanced situation on both sensors. In bright conditions do not allow direct sunlight onto the sensors.
6. Muzzle blast - If the muzzle blast reaches the first sensor before the projectile, your results will be bad or not at all. If the muzzle blast causes your screens to shake, the readings can be bad.
7. Spacing. Make sure that your sensors are properly positioned, secure and the distances are correct. If they are off by even 1/16" it will cause incorrect readings.
8. Glints - If there is water, sand, shiny metal or bright concrete on the ground below your tripod / chronograph set-up, the sunlight will bounce (reflect) off the surface shining back up on the projectile preventing the sensors from detecting a light drop (shadow) and thus result in a poor or no reading situation. Even paint the screen stand matt black to stop reflection.
9. Indoor - Fluorescent lighting is the kiss of death to any chronograph system. Their light does not allow the sensors to "see" the bullet. For indoor and low light conditions use either a light box with diffused incandescent lighting or the newer infra red light system.
10. Other variables - Depending on the quality of the chronograph & sensors, other variables such as mobile phone transmissions and high tension poles or electrified fencing can all have effects on chronograph performance. Even high static discharges from thunder storms in the area of use can result in problems.

USING THE RESULTS

Here is a typical 18 shot string used in load development of Service Pistol, using a 150 grain SWC in a .38 Special Case, tested for consistency and Power factor.

862	839	828	820	826	850	841	864	841
843	838	817	859	847	847	849	844	841

Highest Shot 864 fps		Lowest Shot 817 fps	
Extreme Spread	47 fps	Average Velocity	841 fps
Standard Deviation	13 fps	Power Factor	126.1

A spread of 47 fps in 841 (5.5%) across all shots is acceptable with a standard deviation of 13 fps (1.5%) showing me that most of my shots have very small variations. The average power factor is also within my desired range of 125 – 128. If I apply the worst case scenario of the lightest projectile (148.6 grain) multiplied by the slowest speed (817 fps) I still get a power factor of 121.4 which is a small margin over the minimum for the Service match.

TIPS ON SETUP

Set your chronograph up on a range with a good backstop and preferably with a good shooting rest (sandbags are the best rest), my preference is a range with a bench and a chair to shoot from. You do not have to put a target downrange, but it may help some people to shoot over the screens (not into the Screens). The screens are normally mounted on a camera tripod downrange.
Because the screens will measure anything that changes the light level setting up is critical. If you set the screens too close to the bench the front screen can pick up the muzzle blast as well as the bullet. When shooting subsonic ammo, the muzzle blast will reach the first screen before the bullet.

As a rule most chronographs with separate screens have about 5-6 metre cables. Set the screens so the furthest screen is near full cable length away. The folding Chrony should be set at least 3 metres away, and increase this if gives an error with muzzle blast.
The light level should be the same for each screen, not one in sun and one in shade. For full sun use the covers over the screens, for overcast days you can leave them off. Most factory light diffusers or covers are very narrow, and you have to be careful not to allow direct sunlight on to the lens of the screen, wider covers cut from white core flute have worked very well on a number of different chronographs.
The typical shooting area is 10-15 cm above the screens directly over the two lenses.

MYTH'S 1/. The Nationals last year a debate over pointing a pistol vertical and tapping the powder to the rear prior to testing, so it would achieve a higher velocity turned into a nightmare. I will not enter the referee discussion on how to test, but did manage to prove the myth.
On large capacity cases .38 special and, .357 Magnum (loaded with fast burning powder and having a lot of airspace), tapping the powder to the rear will produce 20 – 30 FPS faster than tapping the powder to the front of the case. I could not produce this effect with 9mm cases and slower powders. But the smaller cases with a bulky powder have repeatedly produced tighter Extreme Spreads and lower Standard Deviations than the bigger cases.
2/. Loading for a 120 power factor is a myth. Having looked at and seen the errors that are evident in the chronographs, our loads and environmental factors. Anybody loading to just make factor deserves to fail often.
A reasonable compromise would be to load for the 4 % error (taking the factor up to 125) plus environmental allowance (loading in Tasmania to shoot in Alice Springs etc).
Knowing more now, I load for 125-128 factor and if I see a poor chronograph set up, I have the knowledge to challenge it.

ALWAYS WEAR EYE AND EAR PROTECTION WHEN CHRONOGRAPHING.
BEFORE YOU FIRE THAT FIRST SHOT REMEMBER -

"He who shoots the Chronograph, buys the new one"

Notes: Photos of chronographs and screens have been removed to reduce file size.

http://www.pilkguns.com/Chrony.shtml