The Effects of Powder, Barrel Length & Velocity on Distance Determination

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Abstract

Distance determination can be used to show familiarity between shooter and victim, or it could confirm or disprove a suspect's story. This study aims to question whether access to the firearm and ammunition used is really necessary in distance determination. Different barrel lengths, reloading powder type and loads were used to observe differences that may be expected from firearms and ammunition used to fire a bullet of a .357" diameter.

Using four different revolvers and a 357 Magnum rifle, patterns illustrate a wide range of characteristics with a level of inconsistency. There are a number of factors that could play a role in distance determination, but this study showed a good correlation between powder burn rate and maximum distance of GSR (gunshot residue) pattern persistence. With this is mind, further test standards should be completed in a side-by-side manner to determine just how much residue patterns are affected by environmental

factors and normal handling encountered over the course of an investigation compared to laboratory conditions with minimal handling.

Introduction

Frequently, a firearm or the ammunition used in a shooting incident is not present or acquired at the time of the incident, but a bullet may be recovered from the victim. Regardless, investigators may still be interested in the distance of the shooter. Typically, GSR patterns produced using the firearm and ammunition from an incident can aid in determining the distance of the muzzle of a firearm to an object through comparative analysis. Patterns typically consist of a mixture of vaporous lead, nitrites, varying degrees of burned gunpowder and other foulings produced by firing a cartridge.[1 - 4] According to the guidelines set forth by SWGGUN (Scientific Working Group for Firearms and Toolmarks), it is recommended that the actual firearm and similar ammunition be used.[5] But is this really necessary? Experienced firearms investigators may have the ability to theorize the distance based solely on the appearance of the pattern prior to any pattern testing, but how accurate can this estimate be, or rather how inaccurate can it be? Studies have been done on the effect of varying cylinder gap, utilizing the same make, model and barrel length of firearm but also different barrel lengths.[6 - 9]

In L. Haag's study on cylinder gap effects on GSR pattern he showed an inverse correlation between pattern density and cylinder gap distance. As one might expect, the increased cylinder gap allowed more gases and unburned particles to travel out the sides of the gun, rather than down the barrel and toward the target.[8]

L. Crego's research on distance determination between same make, model and barrel length showed that keeping the firearm similar to the suspect's firearm may be sufficient for distance determination. The study evaluated a variety of firearms with barrel lengths ranging from 3.5" – 5.0" (8.89 – 12.7 cm) and made use of the same ammunition type throughout.[7]

Whereas A. Brudenell's study focused on differences of gunshot residue patterns produced by using only 2 firearms, a pistol and a pistol carbine. Using these two firearms, he observed a variety of characteristics from macro- and microscopic evaluation, chemical enhancement and velocity produced by 3 different types of ammunition. The study ultimately concluded that the carbine produced tighter patterns to further distances and there may be distinguishing characteristics to further separate the partially unburned powder particles produced by the two different firearms.[6]

The focus of this study will run in the same vein of these previous studies and show the effects of bullet velocity, powder type, and different barrel length on the patterns produced for comparative value. To be of a more general value, only comparative methods used in most labs were employed, namely visual comparison and chemical enhancement tests: the Modified Griess Test and Sodium Rhodizonate Test. Each type of cartridge used was fired from 3" (7.62 cm) to whatever distance at which it stopped producing an observable pattern which was subjectively set at 10 readily visible particles per target area. The targets were then compared to each other to note any consistencies or inconsistencies.

Due to the rise in popularity with reloading and given the possibility of reloaded ammunition being used in a crime, several batches of cartridges were loaded with different powders at minimum and maximum loads.[10-15] This added more control over the velocity of the cartridges and allowed visualization of any alterations of the patterns seen at different velocities. It also provided for selectively choosing powders based on both burn rate and morphology in an attempt to produce the greatest potential variance. Common factory cartridges produced by the most widely distributed US ammunition manufacturers were also included as they are often seen in shooting incidents.

As previously mentioned, firing a firearm results in smoke and microscopic particles being ejected along with the bullet out of the muzzle. These same particles will be released from the ejection port or the cylinder gap of a revolver.[8] For this study we were only interested in the residues being projected forward from the muzzle and their deposition on a target of varying distances. More precisely, the study assumed that the only pieces of evidence provided were a bullet measuring .357" in diameter and a potential residue pattern. It is well known among examiners that a .357" diameter bullet with cannelure was very likely fired in a 38 Special or 357 Magnum chambered firearm. Although these two cartridges have the same bullet style and diameter, they typically have very different velocity outputs.

The longer case of a 357 Magnum cartridge allows for a higher powder charge, resulting in higher potential velocities. A 357 Magnum firearm can safely fire either a 38 Special or a 357 Magnum cartridge. The firearm would be chambered to the same diameter in either case, but the 357 Magnum is also engineered to handle the extra pressure created by the higher energy cartridges. On the other hand, a 38 Special firearm is not meant to accommodate the longer case or high pressure peaks of a 357 Magnum cartridge. But with only a bullet of .357" diameter and ambiguous mass, 125 grains in this case, an examiner would not be able to tell the specific cartridge utilized in the firearm. A grain is a "unit of weight equal to 0.065 gram, or 1/7,000 pound".[16]

With the caliber being narrowed down to two likely possibilities, there still remains the question of what kind of firearm fired the cartridge. This could result in a wide variety of firearms and barrel length ranging from semiautomatic pistols to rifles. This study focused mainly on the varying barrel lengths of revolvers, though a rifle chambered for 357 Magnum was also briefly studied. There are also semiautomatic handguns chambered for 357 Magnum, such as the Desert Eagle, that were not tested that could extend the potential list of suspect firearms.

And with the increasing possibility of reloading, the characteristics of the ammunition being shot from one of these calibers with a range of firearms must also be taken into consideration. Different reloading powders have different burn rates, morphologies, and can be adjusted to a shooter's preference. This small study was an attempt to take these factors into consideration to see how they could potentially affect the distance determination of an examiner given minimal clues and physical evidence. Given the focus of potential effects, replicates were not produced to test for reproducibility. Further tests should be run with a solid backing and in replicate to test the reproducibility of maximum distances along with introduction of environmental factors, blood, and normal handling.

Materials and Methods

Firearms

- Smith & Wesson® 357 Magnum Revolver model 686 - ~ 8 3/8" Barrel
- Smith & Wesson® 357 Magnum Revolver model 66-1 - ~ 4" Barrel
- Smith & Wesson® 357 Magnum Revolver model 19-4 - ~ 2.5" Barrel
- Smith & Wesson® 38 Special Revolver model 10-5 - ~ 2" Barrel
- Rossi® .357 Lever Action Rifle Model 92 SRC - ~ 20" Barrel

Ammunition

Factory cartridges were tested along with reloaded cartridges to expand the potential variety of ammunition types. An attempt to use typical factory cartridges often seen in case work was made but is by no means exhaustive. An effort was also made to reload with commonly available and most frequently used reloading powders. All cartridges were reloaded with CCI® 500 Small pistol primers except for the 357 Magnum cartridges which utilized Blue Dot® Powder where CCI® 550 Magnum Primers were used. All reloaded cartridges used an unlabeled bulk box of 125 Gr. (grain) JSP (jacketed soft point) bullets. Note that other ammunition types, JHP (jacketed hollow point), FMJ (full metal jacket) and LWC (lead wad cutter), were also used.

Factory Cartridges

- Remington® 357 Magnum 110 Gr. JHP – Lot # J30UB8117
- Winchester® 357 Magnum 110 Gr. JHP – Lot # 1157PD2185
- Federal® 357 Magnum 110 Gr. JHP – Lot # 17A-0228
- Remington® UMC 357 Magnum 125 Gr. JSP – Lot # L357M12

- Remington® UMC 38 Special 130 Gr. FMJ – Lot # L38S11
- Winchester® 38 Special 148 Gr. LWC – Lot # 27UF50

Reloading Powders and Charge Loads

- Alliant Blue Dot®:
  - 38 Special Load @ 7.5 Gr.
  - 357 Magnum Load @ 12.0 Gr.
- Accurate No. 5®:
  - 38 Special Load @ 6.1 Gr.
  - 357 Magnum Load @ 11.0 Gr.
- Alliant Unique®:
  - 38 Special Load @ 5.0 Gr.
  - 357 Magnum Load @ 9.6 Gr.
- Alliant Bullseye®:
  - 38 Special Load @ 4.0 Gr.
  - 357 Magnum Load @ 8.0 Gr.
- Hodgdon Clays®:
  - 38 Special Load @ 3.5 Gr.

Targets

Targets consisted of a 9" x 9" (22.86cm x 22.86cm) Texwipe® (TX309) Wiper affixed to an 8.5" x 11" (21.59 x 27.94 cm) Exact® Vellum Bristol 67 lb. Wausau Paper with Scotch tape. The target was then affixed to a standard cardboard box acting as a baffle board. A confined area behind the target was removed from the cardboard box to minimize any reduction in bullet velocity.

Chemicals

Modified Griess Test

- 15% Glacial Acetic Acid
- Nitrite Positive Swabs
- Desilvered photo paper treated with sulfanilic acid and alpha-naphthol solution

Sodium Rhodizonate Test

- Sodium Rhodizonate solution (prepared at time of testing)
- 2.8 pH buffer solution (sodium bitartrate and tartaric acid in distilled water)
- 5% HCl Acid solution

Procedure

Reloading

Cartridge cases were produced by firing similar lots of Smith & Wesson® nickel plated ammunition for each cartridge. The fired cartridge cases were then tumbled clean using a standard cartridge tumbler utilizing corn cob and brass polishing media. The cases were then sorted by appropriate cartridge. Bullets were individually measured and separated within a range of one-tenth of a grain weight difference. This was done to minimize velocity differences within a given batch of reloaded ammunition.

To produce reloaded cartridges, a Dillon Precision® “Square Deal ‘B’” progressive reloading press was used. Though this device allows for powder dispensing, each cartridge's powder load was manually measured and dispensed by hand. This was done in an attempt to reduce velocity variability from shot to shot. Each cartridge case was resized, received a new primer and the case mouth was flared prior to manual powder distribution. The precision of the scale used was two-thousandths of a grain. All powder charges were measured to the maximum and minimum specifications determined to be safe by various sources including reloading manuals and manufacturer websites.[11-15]

After powder distribution, the cartridge case was again set in the reloading press where the bullet was seated to the proper depth. The last stage involved taper crimping the case on the bullet. The device dies were adjusted to accommodate the cartridge length difference between 38 Special and 357 Magnum at which point the process was repeated.

Test Firing

All test fires were performed in an indoor, sound-insulated, and properly ventilated firing range. Each shot was fired from a Ransom Rest® affixed to a wooden board that was clamped into a work bench. All revolvers were fit into the same L-Frame mold cutouts made for the Ransom Rest®. A baffle box was set up to insure no sound waves interfered with the chronograph screens' bullet velocity reading. An Oehler Research® Model 55 chronograph system was set up with a 3' (91.44 cm) spacing between screens. This spacing was found to be the optimal distance for recording velocities at this range while also maximizing space for target-muzzle distance modification with the constraints of the firing range. The front screen was set up approximately 5' (152.4 cm) downrange from the muzzle of the firearm with the target workbench set up between the firearm and front screen. After setup, the screens nor the ransom rest bench were moved aside from minor adjustments to line up the sights. The target work bench was adjusted to the desired distance between muzzle and target. The target workbench consisted of the target affixed to the baffle box that was weighted with phone books and set on top of a portable workbench.

Instead of using the provided lever of the Ransom Rest® to depress the trigger, the lever was removed and string with a slip knot was tied lassoing the trigger and Ransom Rest®. The hammer was cocked into a single-action ready position and the string was pulled behind a plexiglass safety screen for safety purposes.

After each shot, the target was retrieved, labeled with a pattern number, ammunition type, cartridge type, barrel length, distance and the velocity at which the pattern was produced. It was then placed in a manila folder labeled with the corresponding pattern number and set aside for filing. The target was then set to the next distance to be tested and the process repeated. Distance was determined using a standard metal measuring tape and length was set at the proper distance from the firearm muzzle to actual target. Alignment of sights was verified with every shot and correct distance confirmed after adjustment. The distances used were 3”, 6”, 9”, 12”, 18”, 24”, 30”, 36”, 42”, and 48” (7.62, 15.24, 22.86, 30.48, 45.72, 60.96, 76.2, 91.44, 106.68, 121.92 cm).

One ammunition type was used until it no longer produced a pattern which was subjectively set at 10 particles per target area, a 9”x9” (22.86 x 22.86 cm) wiper. After a maximum distance pattern was produced, extreme spread, average and standard deviation of the bullet velocity were recorded for that ammunition type used in the corresponding firearm. This process was repeated until all combinations of ammunition and firearms were exhausted. All patterns were produced, collected, and photographed prior to any chemical testing. All photographs were taken using a Sony Cyber-shot model DSC-WX100. Chemical tests were conducted as late as 3 weeks after the first pattern was produced.

Chemical Testing

All chemical reaction tests were performed in a fume hood. To prevent interference with subsequent tests, the Modified Griess – Direct Application Technique was conducted first per SWGGUN examination sequence recommendation.[5] This test is used to detect nitrite particles produced by the burning of gunpowder particles. Through a chemical reaction, an orange color change can be observed and may aid the investigator in visualizing latent patterns of nitrites.[1] Desilvered photo paper was treated with a 50:50 mixture of sulfanilic acid and alpha-napthol solutions prior to testing. In an attempt to keep loose particles trapped between the target and photo paper, the photo paper was laid face down on the target, the manila folder was closed and carefully flipped upside down. The photo paper with target on top was then moved to the fume hood. A clean piece of cheese cloth was then dampened with a 15% glacial acetic acid and wrung out prior to being placed on the back of the target. A hot iron was pressed on top of the cheese cloth allowing nitrites to be transferred to photo paper producing an orange chromophoric reaction.

The cheese cloth was then removed and discarded. Both target and photo paper were removed from fume hood and separated. The photo paper was labeled with the corresponding pattern number and the target was allowed to dry prior to future testing. Many patterns were tested prior to documentation by photo scanner. After a small batch was produced, and photo paper dried, resulting Modified Griess patterns were scanned to file. Only select patterns were chemically enhanced based on the visual appearance and significance. An attempt was made to enhance a variety of patterns with different powder morphologies.

The Dithiooxamide Test was not run on any of the resulting patterns. The Sodium Rhodizonate – Direct Application Technique was employed next. A Sodium Rhodizonate solution was made to a dark tea color prior to testing as the solution is only reactive for a few hours. Sodium Rhodizonate can be utilized to help visualize possible gunshot residues not readily visible to the human eye.[2] These residues are commonly produced by ignition of the primer and lead is often found along with barium and antimony in a single molecule.[4] Sodium Rhodizonate also utilizes a purple color change, after HCl application, to help the examiner visualize likely lead particulate.

The target was kept with its cardstock backing so that no previous chemical reactants left by prior Sodium Rhodizonate tests would interact with new target. Each of the chemicals used in this test were applied using identical spray cans. First, the Sodium Rhodizonate solution was sprayed evenly and directly onto the target. It was then allowed to penetrate for approximately a minute prior to applying the buffer solution. The target was allowed time to undergo color change reactions prior to being photographed. After photo documentation, the target was taken back to the fume hood where the 5% HCl acid solution was sprayed on. Again, after a purple color change occurred, the target was photographed for a second time capturing any positive lead reactions. The treated target was set aside and the next target was processed. This process was repeated until all targets were tested.

Results

Below are summaries of the overall velocity statistics of 38 Special and 357 Magnum, Tables 1 & 2 respectively. Table 3 tabulates the maximum pattern distance produced by each ammunition type when fired from each firearm. Also, included in this table is the velocity of the bullet at which the maximum pattern distance was produced.

38 Special Velocity Stats (Feet per second)				
	Minimum Velocity	Maximum Velocity	Velocity Spread	Average Velocity
All Barrels	622	1003	381	796
2" Barrel	622	788	166	696
4" Barrel	676	937	261	797
8 3/8" Barrel	721	1003	282	882

Table 1 38 Special Velocity Statistics

357 Magnum Velocity Stats (Feet per second)				
	Minimum Velocity	Maximum Velocity	Velocity Spread	Average Velocity
All Barrels	1125	2170	1045	1436
2.5" Barrel	1125	1352	227	1236
4" Barrel	1210	1510	300	1329
8 3/8" Barrel	1316	1710	394	1477
20" Barrel	1749	2170	421	1956

Table 2 357 Magnum Velocity Statistics

Maximum Distance Representation by Barrel Length							
	38 Special			357 Magnum			
	2" Barrel	4" Barrel	8 3/8" Barrel	2.5" Barrel	4" Barrel	8" Barrel	20" Barrel
Remington® 110 JHP 357 Magnum				48" @ 1214 fps	42" @ 1268 fps	48" @ 1509 fps	
Win 110®JHP 357 Magnum				30" @ 1191 fps	30" @ 1269 fps	30" @ 1475 fps	
Federal® 110 JHP 357 Magnum				30" @ 1270 fps	24" @ 1383 fps	30" @ 1478 fps	
Remington ®UMC 125 JSP 357 Magnum				48" @ 1269 fps	30" @ 1373 fps	42" @ 1618 fps	36" @ 2166 fps
Remington® UMC 130 FMJ 38 Special	30" @ 703 fps	36" @ 769 fps	42" @ 901 fps				
Winchester® 148 LWC 38 Special	30" @ 711 fps		30" @ 768 fps				
Blue Dot®	30" @ 716 fps	36" @ 801 fps	36" @ 988 fps	36" @ 1152 fps	30" @ 1282 fps	36" @ 1429 fps	42" @ 1805 fps
Accurate No.5®	24" @ 652 fps	36" @ 786 fps	36" @ 863 fps	30" @ 1202 fps	30" @ 1210 fps	36" @ 1501 fps	
Unique®	18" @ 761 fps	18" @ 888 fps	24" @ 905	24" @ 1287 fps	18" @ 1333 fps	24" @ 1500	

			fps			fps	
Bullseye®	18" @ 673 fps	24" @ 769 fps	30" @ 868 fps	24" @ 1169 fps	18" @ 1235	24" @ 1379 fps	
Clays®	12" @ 644 fps	12" @ 730 fps	12" @ 737 fps				

Table 3 Barrel Length vs. Distance

Discussion

Most firearms experts may be able to look at a pattern and offer an estimation based on previous experience they have gained over years. And there are definite trends to be noted such as, a contact shot often produces physical ripping and tearing, close range shots typically produce smoke patterns and as the shooter's distance increases, the pattern diameter will likely increase and particle density will likely decrease. But are the specific firearm and ammunition really necessary to determine shooter distance?

All ammunition produced a maximum distance smoke pattern between 9" – 12" (22.86 – 30.48 cm). The more dramatic differences in patterns were seen beyond this range. Bullet velocity will generally increase as the length of the barrel increases up to an optimal length. On average, over all cartridges used, 38 Special cartridges produced bullet velocities of 796 feet per second (fps) and 357 Magnum produced velocities of 1436 fps. This average changed when separating velocities based on barrel length. See Tables 1 & 2 for a breakdown of bullet velocities of each cartridge type.

Chart 1 shows the correlation between velocity and maximum distance of pattern production.

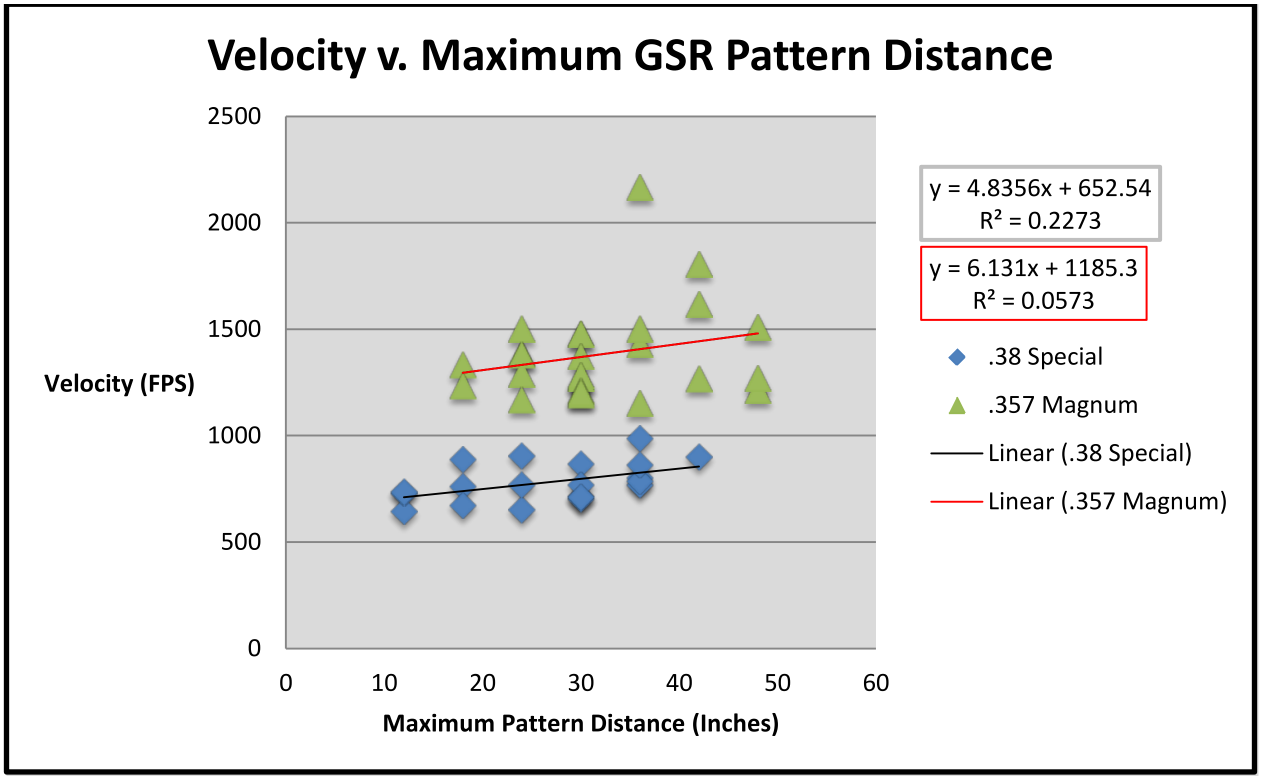

Chart 1 Velocity vs. Maximum GSR Pattern Distance

Barrel length also shows a loose correlation, but there is the added effect of barrel length increasing velocity to take into consideration. Chart 2 graphs the data and Table 3 offers the numerical values of the patterns produced at the maximum distances. Aside from a few outliers, namely the short pattern distance of Hodgdon Clays® powder across all three barrel lengths and the unusually lengthy patterns formed by the 2.5" (6.3 cm) barrel, there is a slight correlation between barrel length and maximum pattern distance. The pattern data produced by the 2" (5.08 cm) S&W®10-5 and 2.5" (6.3 cm) S&W® 19-4 have been lumped together as half inch difference would seem negligible. But note, that the furthest patterns produced by the 2” (5.08 cm) barrel group were fired from the 2.5” (6.3 cm) S&W® 19-4. Also, it should be kept in mind that cylinder gap differences between revolvers were observable by the naked eye. Though not to the extreme that Haag tested, it is a factor proven to affect GSR patterning.[8]

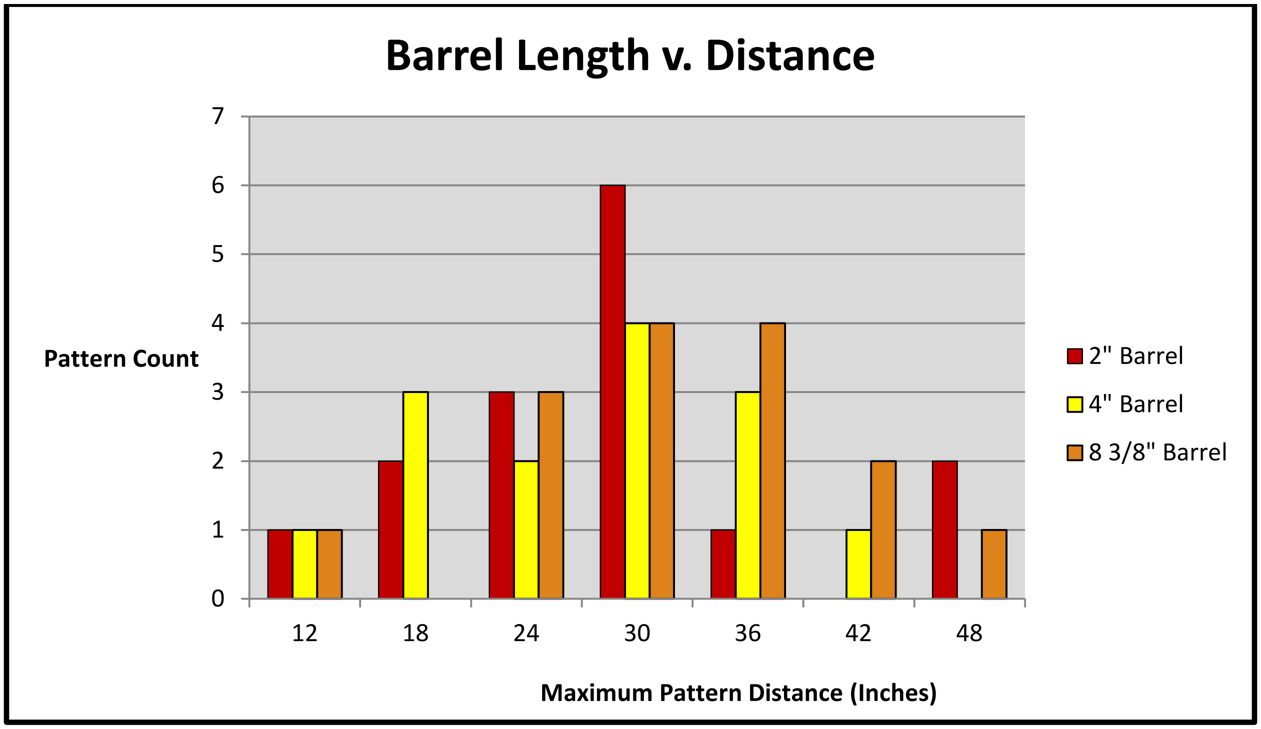

Chart 2 Visual representation of the number of times a maximum distance was reached while using a firearm of the corresponding barrel length.

The last factor taken into consideration was powder burn rate. Chart 3 illustrates the trend seen when assigning relative burn rates to the firearm powders used in the ammunition. Testing indicates that fast burning powders are mostly consumed in the barrel and do not produce patterns at distances as great as the slower burning powder. And slower burning powders start to drop out later than faster burning powders and persist further.

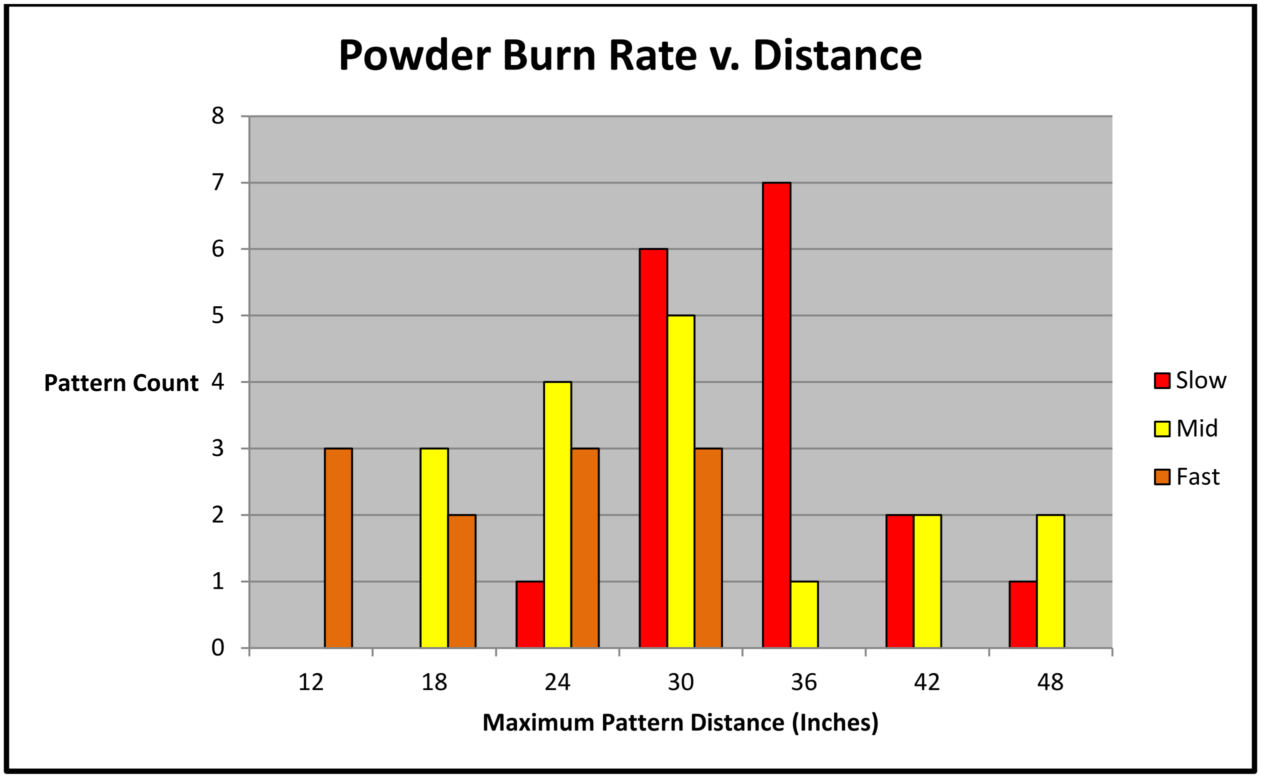

Chart 3 Visual representation of the number of times a maximum distance was reached while using a powder of the corresponding relative burn rate.

Figures 1 – 4 illustrate the cleanest burning powder used and the series of patterns produced. The Hodgdon Clays® powder was one of the fastest burning powders and also the cleanest burning powder and left no visible pattern past 12" (30.48 cm). Figures 5 – 11 will illustrate patterns produced by Alliant Blue Dot®, the slowest burning and dirtiest reloading powder used. Though it left the most unburned powder on the target, it did not produce the furthest pattern.

Figure 1 Hodgdon Clays®3.5 Gr. fired from 2" barrel at 3" distance

Figure 2 Hodgdon Clays® 3.5 Gr. fired from 2" barrel at 6" distance

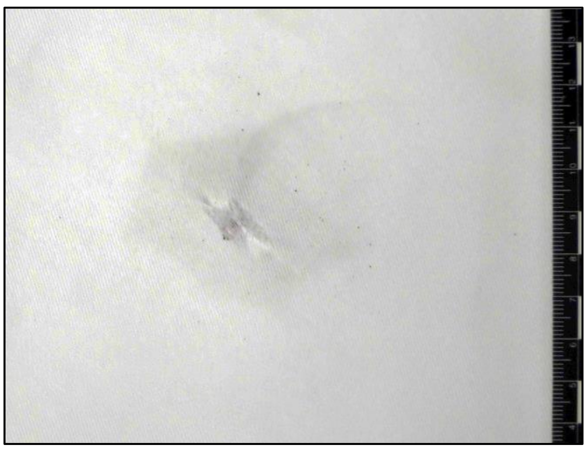

Figure 3 Hodgdon Clays® 3.5 Gr fired from 2" barrel at 9" distance

Figure 4 Hodgdon Clays® 3.5 Gr fired from 2" barrel at 12" distance

Figure 5 Alliant Blue Dot® 12.0 Gr fired from 2.5” Barrel at 3” distance

Figure 6 Alliant Blue Dot® 12.0 Gr fired from 2.5" barrel at 6" distance

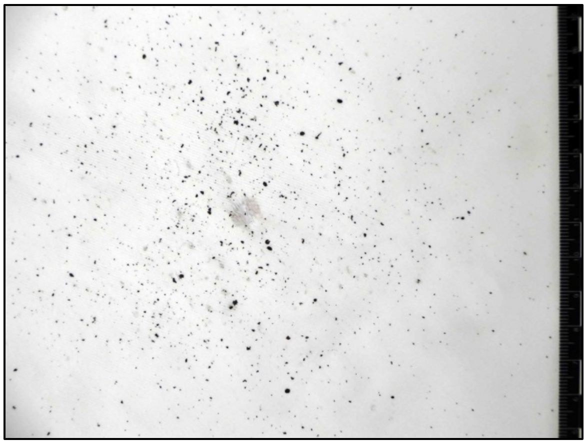

Figure 7 Alliant Blue Dot® 12.0 Gr fired from 2.5" barrel at 9" distance

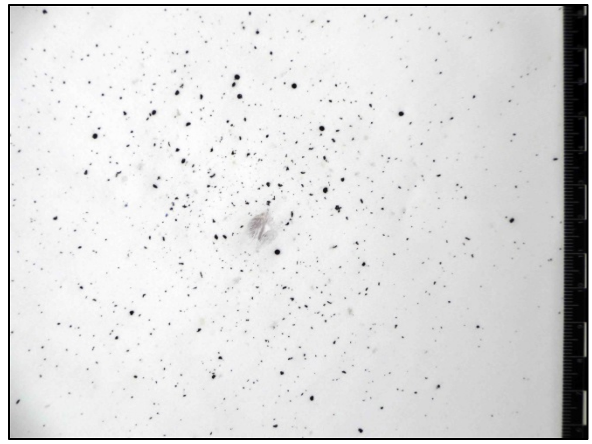

Figure 8 Alliant Blue Dot® 12.0 Gr. fired from 2.5" barrel at 12" distance

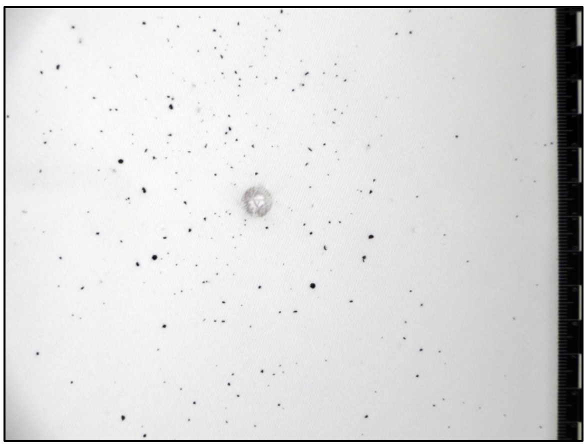

Figure 9 Alliant Blue Dot® 12.0 Gr. fired from 2.5" barrel at 18" distance

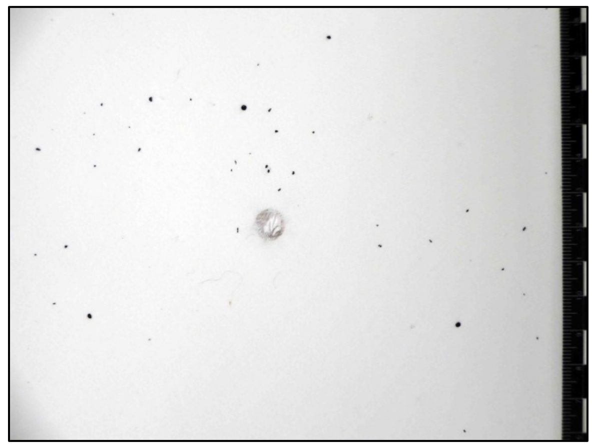

Figure 10 Alliant Blue Dot® 12.0 Gr. fired from 2.5" barrel at 24" distance

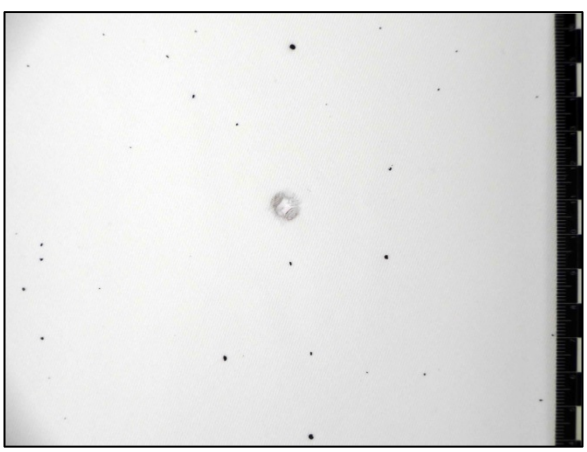

Figure 11 Alliant Blue Dot® 12.0 Gr. fired from 2.5" barrel at 30" distance

Figure 12 will show that even at 48" (121.92 cm), some factory ammunition was still able to deposit gunpowder residues. The residues deposited were of a very small diameter and a light tan color but were readily visible to the naked eye. The resulting image does not fully convey what was seen, but does capture some of the pattern presence. At these distances, chemical enhancements either did not or very lightly enhanced material traces as seen in Figures 13 – 15. Note that Figure 15 does test positive for the bullet wipe which is still of investigative value.

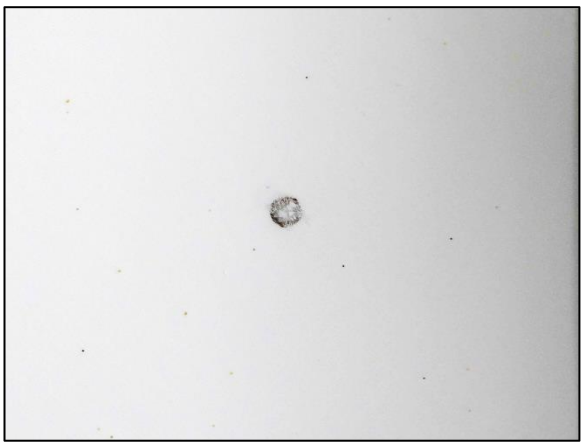

Figure 12 Remington® 110 JHP fired from 8" barrel at 48" distance

Figure 13 Remington® 110 JHP fired from 8" barrel at 48" distance, Modified Griess Test

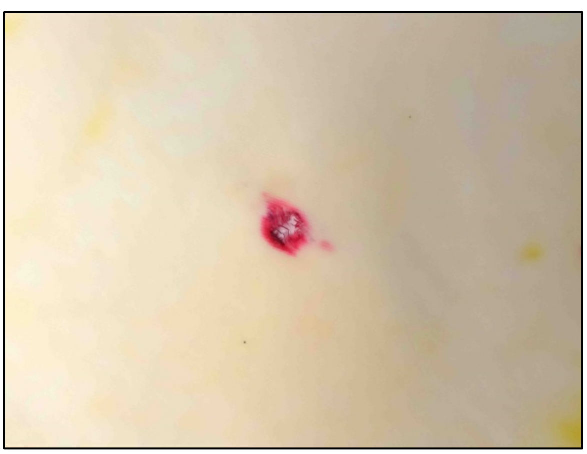

Figure 14 Remington® 110 JHP fired from 8" barrel at 48" distance, Sodium Rhodizonate Test

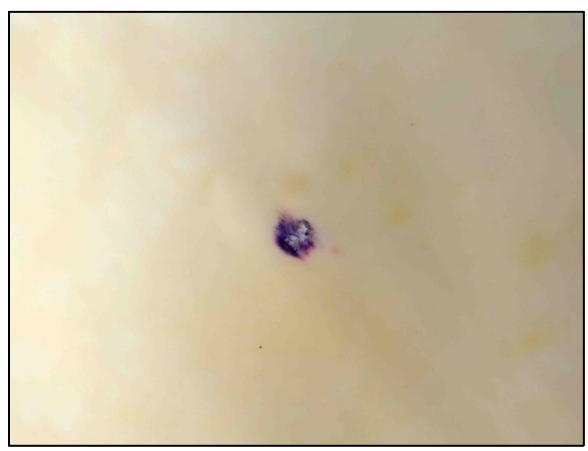

Figure 15 Remington® 110 JHP fired from 8" barrel at 48" distance, Sodium Rhodizonate positive lead confirmation after HCl application

Conclusions

In conclusion, many trends that are readily visible can be fairly accurate. Trends such as a contact shot often produces physical tearing and ripping, a gunshot at close range will likely produce a smoke pattern up to 12” (30.48 cm) even with the cleanest burning powder, and as a shooter’s distance increases, the pattern will typically become wider and less dense. But this study has shown that there are a variety of factors at play and the ammunition used in the incident is highly desirable to be used in pattern testing for distance determination. Maximum pattern distances can range anywhere from 12” – 48” (30.48 – 121.92 cm) but, with these specific cartridge types, average about 30” (76.2 cm) of maximum distance.

Velocity of the bullet showed a very weak correlation to the maximum distance, whereas barrel length showed a small but inconsistent connection to the maximum distances produced. The most obvious correlation drawn from this study is the burn rate of the powder used in the ammunition in question. This study seems to show that the faster the relative burning rate of the powder, the lower the maximum distance of a GSR pattern is.

This was not an exhaustive study and burn rates were only relative and not definite. More firearms of this caliber would have to be studied to show whether the firearm is truly necessary or would all firearms of this caliber fall within a very short range of one another. And though patterns were produced up to 48” (121.92 cm), residue particles were very loosely adhered and would most likely not survive normal handling seen in real world conditions. Other patterns had such small particles, that chemical enhancement tests did not pick up or enhance them. Further studies should be conducted to determine how much residue is lost in a simulated situation where environmental, blood, and normal handling factors are put into place.

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