Effect of Barrel Length on the Muzzle Velocity and Report from a *Mosin-Nagant* 7.62x54R Rifle

Brandon Louis Clark

Honors College
University of South Florida
Tampa, Florida USA

May 2011

ABSTRACT:

The present paper describes an experimental study into the effects of barrel length for the Mosin Nagant 7.62x54R rifle. The parameters investigated were primarily the muzzle velocity and quality of sound produced i.e. report. The original barrel length of 28.75 inches was reduced to a final length of 16.75 inches in two inch increments. At each barrel length a digital chronograph was utilized to measure projectile velocity approximately ten feet downrange, while the sound profile was recorded via a microphone and audio software on a laptop computer. Testing took place in a single day, outdoors in a rural location in Manatee County, Florida. Weather conditions were sunny with a slight breeze, but the range was in a sheltered location between medium brush. 10 rounds of ammunition were fired for each barrel length in order to average the results

INTRODUCTION:

The Theoretical Rifle

The barrel length is a pinnacle factor of consideration in the choice of any firearm; Robert A. Rinker continues “Barrel length is an important factor in bullet efficiency as it relates to chamber pressure and the expansion of gas… (barrel length is) important in relationship to velocity figures and generally, the longer the barrel the higher the velocity” [1]. Barrels come in a variety of forms, from tapered barrels whose cross sectional area decreases with increasing length to bull barrels, which maintain a relatively large constant cross sectional area the entire length of the barrel. A barrel is characterized by more than just physical dimensions; these previous characteristics are few among the many parameters involved in barrel selection and manufacture. A barrel also may be characterized by its rate of twist (or lack thereof), material properties, cartridge type, et cetera. The only parameter tested in this specific experiment was barrel length variations, all other parameters were held constant, or assumed to have negligible effects on our particular study.

A longer rifle barrel has the advantages of a longer sight radius, theoretically allowing a shooter to obtain a higher degree of accuracy from the improved precision of the sights alone. A longer barrel also provides a longer path for the projectile to stabilize prior to exiting the barrel, while allotting a longer period of time for the propellant charge to act on the projectile, often resulting in higher muzzle velocities and more consistent trajectories. A long barrel inherently provides more mass available for heat transfer, increasing the heat transfer rate incurred between shots, in turn allotting less warpage in the barrel, helping to improve consistency (and ultimately accuracy). A long barreled rifle may also be viewed as safer option to the user. This can be understood by evaluating the increased difficulty to accidentally shoot yourself, as the muzzle becomes farther and farther from your person. This is often a neglected parameter, however, assuming proper and safe firearms operation at all times.

With those benefits stated, a longer barrel also has its negative characteristics. A longer barrel adds bulk to the firearm, undoubtedly adding weight and lowering the overall stiffness of the barrel. One of the most significant effects of a long barrel often criticized by the shooter is its decreased maneuverability; in some applications, a long barrel proves virtually impossible to work with in the field. An example of this may be witnessed by a hunter who is having a hard time maneuvering his/her rifle through heavy brush, as well as having a hard time adjusting their point of aim if their target is moving. With the added weight of the long barrel, the hunter also has a tendency to become tired easier, especially if he/she is required to move during the hunt. For these reasons, large, thick rifle barrels are generally preferred by target shooters, and not hunters in particular. Most hunters are willing to sacrifice some barrel length for the benefits of a shorter rifle barrel, whose pros and cons are elaborated on below.

The short rifle barrel, often referred to as a carbine when installed on a rifle, has the benefits of improved maneuverability. This improved maneuverability is a direct effect contributable to the smaller length of barrel. The barrel length is usually responsible for the majority of the overall length of the rifle; the smaller the barrel, in turn the smaller the overall length, and ultimately the greater the maneuverability. The more compact package of a short barreled rifle has also been shown to attract criminals who use firearms in crimes. This attraction is a result of the increased concealability the criminal may obtain in having the barrel as short as possible. Federal guidelines from the Bureau of Alcohol, Tobacco, and Firearms (BATF) list specific barrel length and overall length limits for rifles and shotguns. While this legal length minimum doesn't do much to deter the criminal, who has little to no regard for the law in the first place, it does limit the amount of barrel reductions available for testing in this experiment.

The shorter barrel requires less material for barrel construction, in turn providing a lower weight. From a manufacturer's stand point, the shorter barrel will cost less due to a decreased amount of material required for construction, with all other parameters held constant. A rifle barrel generally may be analyzed as a cantilever beam supported at the receiver. The overall stiffness of the rifle barrel is improved through a shortened length, as the overall stiffness is inversely proportional to the length of the barrel. The overall stiffness is also related to the diameter of the barrel, as larger barrel diameters contribute to an overall stiffer barrel. Rinker speaks of stiffness advantages in regards to accuracy, "Guns of equal barrel length shoot tighter and more accurate groups if the barrels are stiffer" [2]. The diameter effects regarding overall stiffness and ultimately accuracy was not testing in this specific experiment; however, they're represented here to provide a thorough stiffness evaluation.

It should also be noted, as the barrel length increases, the barrel's center of mass moves further from the geometric center in regards to the rifle itself, and makes the rifle harder to support. In effect, a shorter barrel will tend to keep the center of mass closer to the geometric center of the rifle, a desired effect, as longer barrels tend to produce muzzle heavy rifles which negatively affect shooting conditions.

A short rifle barrel also has the disadvantage of a louder report, since the shooter is becoming closer to the explosion taking place within the barrel. The loud report effects witnessed in carbines may also be attributed to the propellant charge's continued expansion after the projectile has exited the barrel. Further analysis of the internal events occurring within a rifle barrel will show a transitional effect between peak pressure and projectile momentum. At the instant the primer is struck, high temperature expansion gases within the cartridge work against the rear cross sectional area of the bullet. As the bullet resists movement, the pressure builds up until a peak pressure is obtained. The peak pressure is responsible for the majority of the work in accelerating the projectile. At, or shortly previous to reaching peak pressure, the bullet begins to move down the barrel. "When the projectile reaches enough velocity and the space behind it increases enough that the volume of gas is increasing at the same rate, the pressure will begin to drop as the bullet continues and increases the space. The bullet is moving fast enough to supply more space behind it than the advancing gases can fill and maintain pressure, so the pressure drops" [3]. High pressure is characterized towards the start of the barrel, with a transition to projectile momentum dominance occurring in the medium to longer lengths of the barrel. The precise length and location of these transitions is characteristic to the bore and cartridge, but may also be influenced by bullet length, seating depth, and the bullet to case tightness, to name a few. Thus, the louder report of carbines may be explained by the barrel length becoming short enough to enter this primarily pressure dominated region, effectively increasing the gas pressures at the muzzle. In contrast, the less intimidating reports of long barreled rifles may be explained by allowing the barrel length to enter the momentum dominated region of the barrel. Thus, as the projectile exits the long barrel, it is carried out mostly by its own momentum, and has relatively low muzzle pressures.

A similar study in which contact shots were evaluated regarding barrel length changes for a shotgun and rifle produced results which also validate previous claims: "Gas pressure and velocity of the gas jet at the muzzle increases with shortening of the barrel" [4]. Other research on the subject, produced a more quantitative analysis of the report; "Dr. William L. Kramer (Ball State University) found that muzzle blast noise (report) increases 1 decibel for each inch a barrel is reduced" [5]

A short rifle barrel also has the disadvantage of a decreased shooting range, incurred through the decreased muzzle velocity. Higher muzzle velocities generally produce flatter trajectories, a desirable effect among all shooters, but most appreciated by the long range shooter. The decreased muzzle velocity is often due to an inadequate barrel length, and ultimately a lack in allowing the combustion gases to exploit their maximum work potential on the projectile previous to exiting the barrel. Often times this decreased shooting range as a consequence of a short barrel length is negligible for most hunting distances, generally distances below 350 yards; Furthermore, "a .308 (Winchester) 168-grain BTHP Match round will impact 6 inches lower at 500 yards when fired from a 20 inch barrel than when fired from a 24 inch barrel" [6]. Thus, the velocity differences are mostly appreciated by the long range precision shooter. It should also be noted that most ballistic performance charts are referenced to a 24 inch barrel standard.

Short rifle barrels may also negatively affect the barrel life of the firearm. This is due to the increased magnitude of unburnt gases which leave the muzzle in shorter rifle barrels, and is even referenced to in the Official Soviet Mosin-Nagant Rifle Manual: "carbines are subject to more rapid deterioration of the bore at the muzzle due to the greater amount of unburned propellant that passes this point" [7]

The barrel length debate is nothing new to the firearm community, as almost every shooter is quick to add their own thoughts and feelings. These debates are usually plagued with unreferenced and qualitative data, with true unbiased work fairly scarce. Initially, I found this quite surprising given the long period of time in which firearms have been available and tested. Ultimately, It became clear that the lack of experimental data was most likely due to the high cost of testing (ammunition and firearm procurement), as well as the lack of suitable testing equipment. James Kasper and Jim Downey confirmed these claims in their Ballistics by the Inch testing: “In early 2007, Jim Downey and I (James Kasper) searched the web for information related to barrel length, ammunition, and ballistic performance. What information we found was scatter, sketchy and incomplete” [8]. The digital chronograph (used in this experiment) was obtained for a relatively low cost; however, “it was only in more recent years that the cost and ease of owning (a digital chronograph) was within the means of the average person” [9]. Previous to this current era of affordable testing equipment and even the digital chronograph itself, experiments to obtain the velocity of a projectile were quite cumbersome, and surely played a role to the minimal amount of quantitative information available today. It was only as technology advanced, that is was possible for “an amateur (to) accomplish things that not long ago would have created problems for a complete ballistic laboratory” [10]

The Mosin-Nagant Rifle

The Rifle chosen for experimental testing was a surplus M91/30 Mosin-Nagant rifle. This rifle accepts the Russian 7.62x54mm Rimmed cartridge, a cartridge originally created for this specific rifle in 1891. “The Russian 7.62x54mm is the only rimmed military cartridge now in use worldwide. Today’s 7.62x54mm primarily serves as the PK machine gun round.”[11].While the 7.62x54R cartridge (as it is often abbreviated) doesn’t find a large use as per today’s military standpoint; it was originally produced in large quantities and is now primarily used by civilians for recreational purposes.

The large productions of the Mosin-Nagant rifle allotted a large amount of surplus when the respective militaries found the rifle obsolete. Today, the surplus Mosin-Nagant as well as the large market of surplus military ammunition helps these rifles to find homes with many civilians in the US market. Often times these surplus rifles can be bought for less than a couple hundred dollars, and may also be shot for a fraction of the cost in comparison to similarly powered rifles, for example the .308 Winchester round. Low initial investment, low shooting costs and a large market has allowed the Mosin-Nagant to become a favorite among bargain shooters and collectors alike.

The standard M91/30 Mosin Nagant has an average weight of 8.8 lbs. (not including bayonet), an overall length of 48 inches, and a barrel length of 28.7 inches. It should be noted that the rifle used in the experimental testing, had a virgin barrel length of 28.75 inches. The Mosin Nagant barrel can be characterized as a 4 groove rifled barrel consisting of a 1:9.5 inch right hand rifling twist. This may be interpreted as 4 rifling grooves which engage the bullet and force a right handed twist upon the projectile, effectively completing a full revolution of the bullet per 9.5 inches of barrel length.

EXPERIMENTAL SETUP:

APPARATUS

The Mosin Nagant rifle was selected for experimental testing due to its relatively inexpensive cost, reasonably priced military surplus ammunition, and relatively long barrel length. Considering that a rifle was already available and with no external funding means or research grants available, the Mosin-Nagant seemed like a great choice for minimal testing costs. Multiple rounds per barrel length iteration were favored so that a well-structured mean velocity may be obtained. With similar rifle rounds easily approaching a dollar per round, the military surplus rounds could be obtained for a fifth of that price, and allowed multiple rounds to be shot per barrel length iteration without incurring large costs. 147 grain Bulgarian surplus ammunition was used for the experimental testing. As previously mentioned, Federal regulations hold a minimal barrel length of 16 inches as the shortest legal length barrel. With that being said, the relatively long length of the Mosin Nagant barrel, would allow more velocity data to be extracted before reaching the legal length limit of the barrel.

The experimental setup was constructed in a rural outdoors environment. Ideally testing would have taken place within an indoor range, free from the high variability existing in an outdoor environment; however, due to monetary considerations, an indoor range proved unattainable. All the respective testing took place on a single day; March 20, 2011 (from 12 - 7 PM). The conditions respective to the testing date were winds varying from 13-17 mph with an ambient temperature of 83°F. The testing location was in Manatee County, Florida. Shots were taken from a large table, which was strapped and weighted to the soil in order to reduce movement, as seen in Figure 1. Furthermore, a Hyskore® DLX Precision Rifle Rest was then bolted to the table, allowing the rifle to be secured within the rifle rest. Along with the purchase of the rifle rest, came a remote trigger release which was operated manually by the use of a syringe. This allowed the rifle to be fired, without the user needing to manually pull the trigger, as seen in Figure 2. Both Figures 1 and 2 are provided for viewing on the following page.

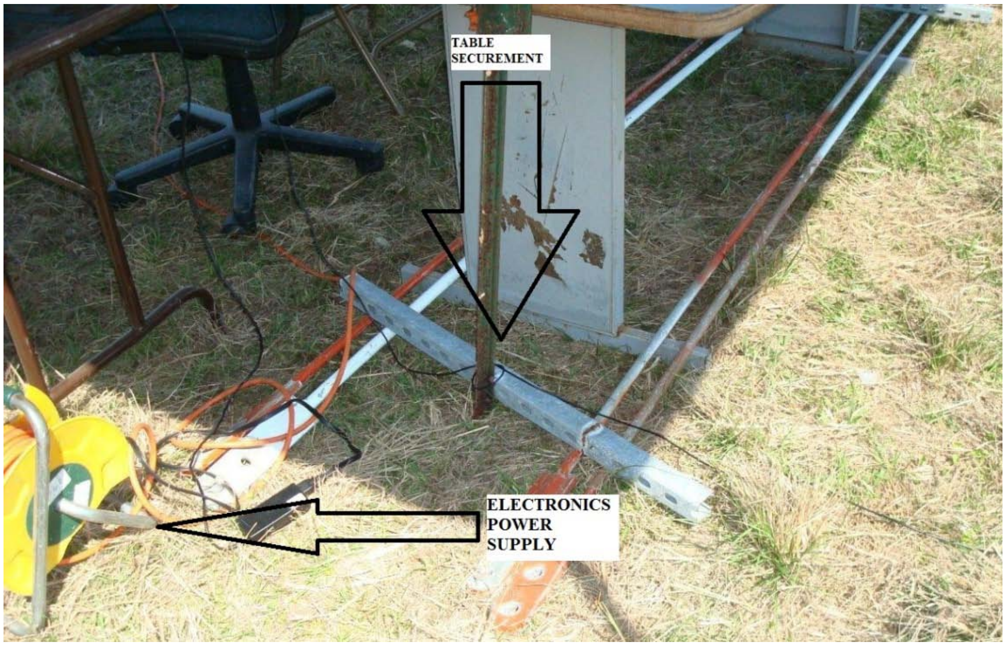


Figure 1: Table Securement allows the reader to see how the table was secured to the soil, as well as illustrating the requirement for a remote power source, since testing took place in a rural environment

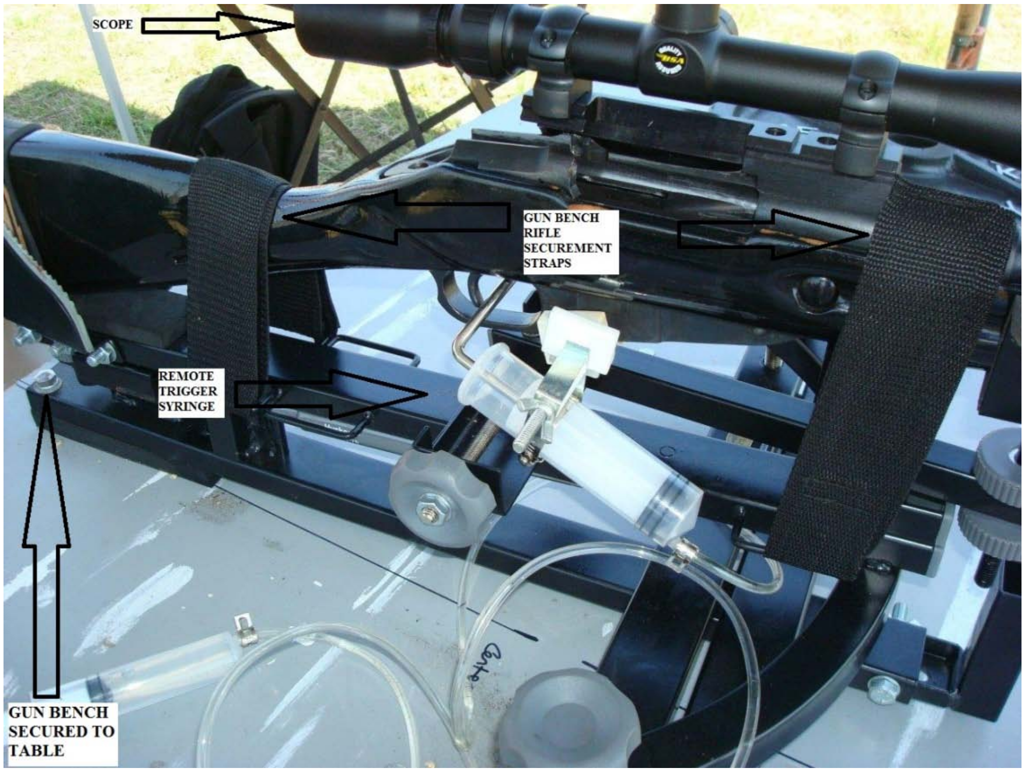


Figure 2: Gun Bench Setup allows the reader to visualize the setup pertaining to the gun bench which housed the rifle during testing. Figure 2 also shows how the remote trigger syringe operated, and effectively allowed remote trigger pulls to occur.

Located on a separate table within the vicinity of the shooting table, were two computers for velocity and sound data acquisition, as seen in Figure 3 below. The velocity data was obtained through the ProChrono® Digital Chronograph located approximately ten feet from the front of the rifle. The chronograph was able to measure the projectile velocity/energy, while also providing the maximum velocity, minimum velocity, average velocity, extreme spread (range), and standard deviation for a string of shots. For each barrel length that was tested, a new shot string was created, and the previous parameters were calculated per each barrel length, with the addition of the median velocity calculation which was added thereafter. The chronograph was connected electronically to the computer designated for velocity measurements, and this allowed quicker data acquisition by imputing the bullet weight into the supplied chronograph program, and exporting the data in the form of an Excel spreadsheet. This may be contrasted for the setup not utilizing an electronically extractable data acquisition. Where in that case, velocities would have to be read off one by one, and the subsequent statistical analysis performed by hand.

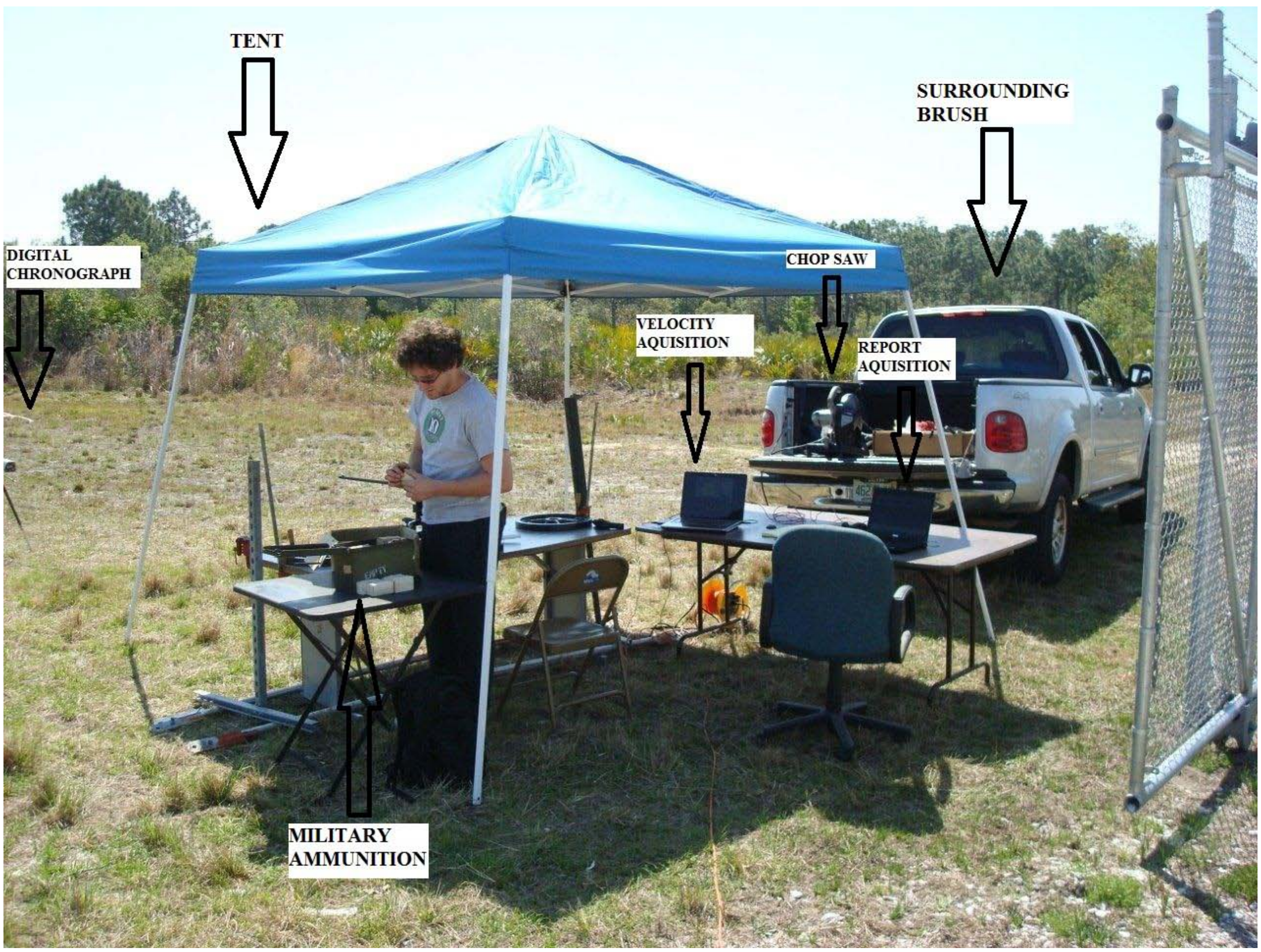


Figure 3: Experimental Layout allows the reader to view the entire experimental testing setup. Figure 3 illustrates table and data acquisition layouts, as well as giving a visual to the surrounding brush conditions.

The sound data was obtained from a microphone located about 5 feet from the rifle, on the designated computer table, as seen in Figure 4 below. The microphone was connected to the computer designated for sound data acquisition with sound data recorded by the audio program Audacity. The implementation of the microphone and Audacity audio program, allowed each shot to be recorded separately and analyzed per each shot.

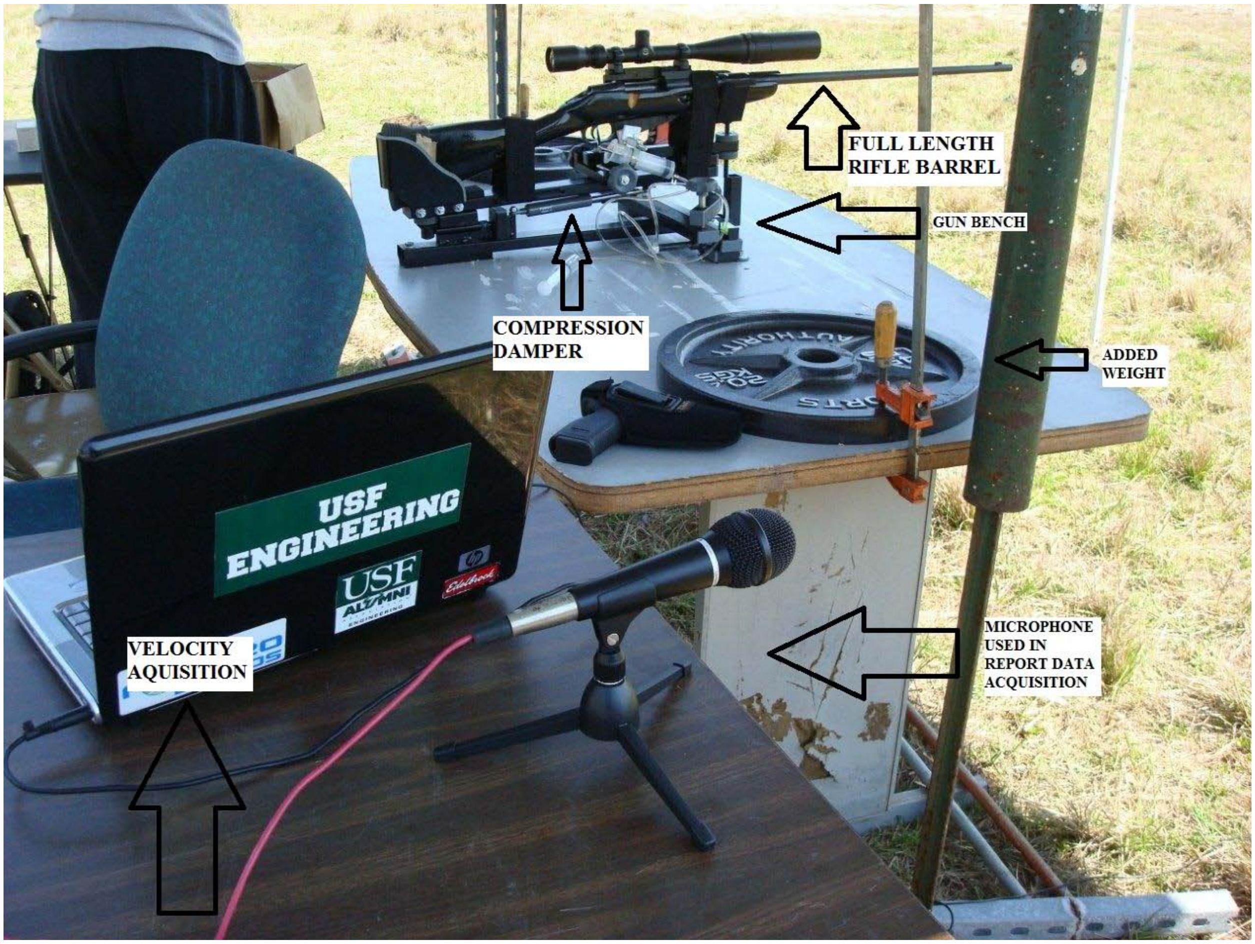
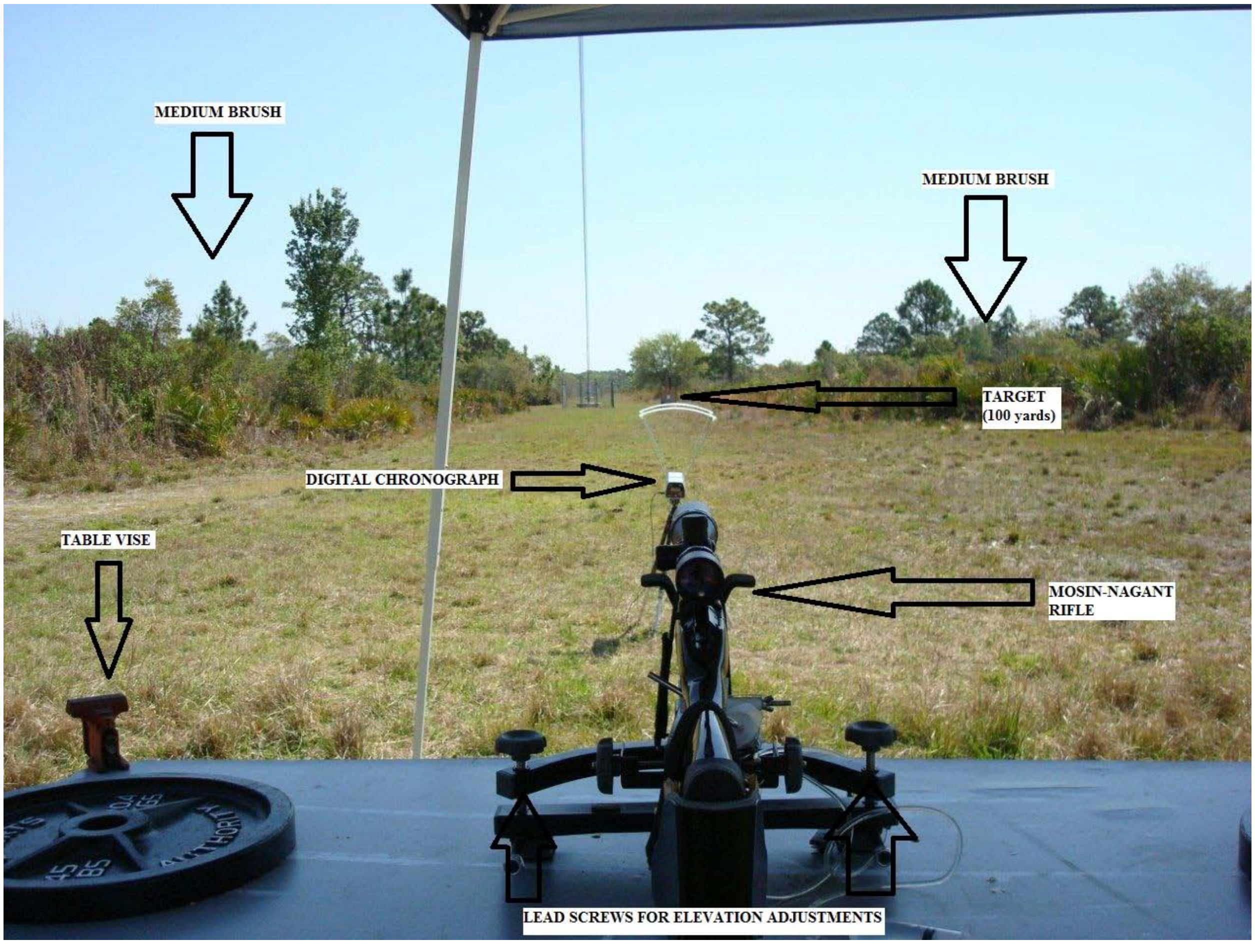


Figure 4: Table Layout allows the reader to view the location of the microphone for report data acquisition. Figure 3 also provides a closer view to the rifle bench setup.

Located 100 yards downrange from the rifle, was a target taped to a metal canister, followed by heavy brush and a tree, providing a positive backstop for the projectiles, as seen in Figure 5 located on the following page. This target was used to extract any possible precision data variances from the rifle, and the target was replaced at the start of each barrel length iteration. Safety is of primary consideration whenever a firearm is to be shot, and due to the nature of the outdoor environment; a positive backstop was the largest safety consideration within the experiment. For if a positive backstop weren't implemented, the ending location of the projectiles could be anyone's guess, and ultimately would prove unsafe given the long range capabilities of the military cartridges.



<u>Figure 5: Downrange Testing View</u> allows the reader to visualize the length at which target shots were made (100 yards). Figure 5 is also effective in laying out the position of the chronograph with respect to the rifle.

The testing took place within a cleared lane surrounded by medium brush. Shooting within the lane of cleared brush aided in decaying the negative effects of ambient wind conditions to the precision shooting characteristics of the rifle.

The Mosin-Nagant rifle used in the experiment was also fitted with a scope mount from Rock Solid Industries. A scope was chosen for implementation in order to help evaluate the precision shooting differences within the rifle, if possible, and it was felt that an exact point of aim would be unobtainable and relative to the shooter if only the standard iron sights were used. After fitting the scope mount to the rifle, a BSA MD624X40 Target/Hunting Rifle scope was selected for use in the experiment. By implementing this particular scope, which offered a maximum magnification of 24 times zoom, the field of view at 100 yards was reduced to 4.7 feet, allowing the point of aim to be confirmed between shots and to help reduce user variations. The Rock Solid Scope Mount, BSA Scope, and final rifle configuration may be seen in Figures 6-7 located on the following pages.

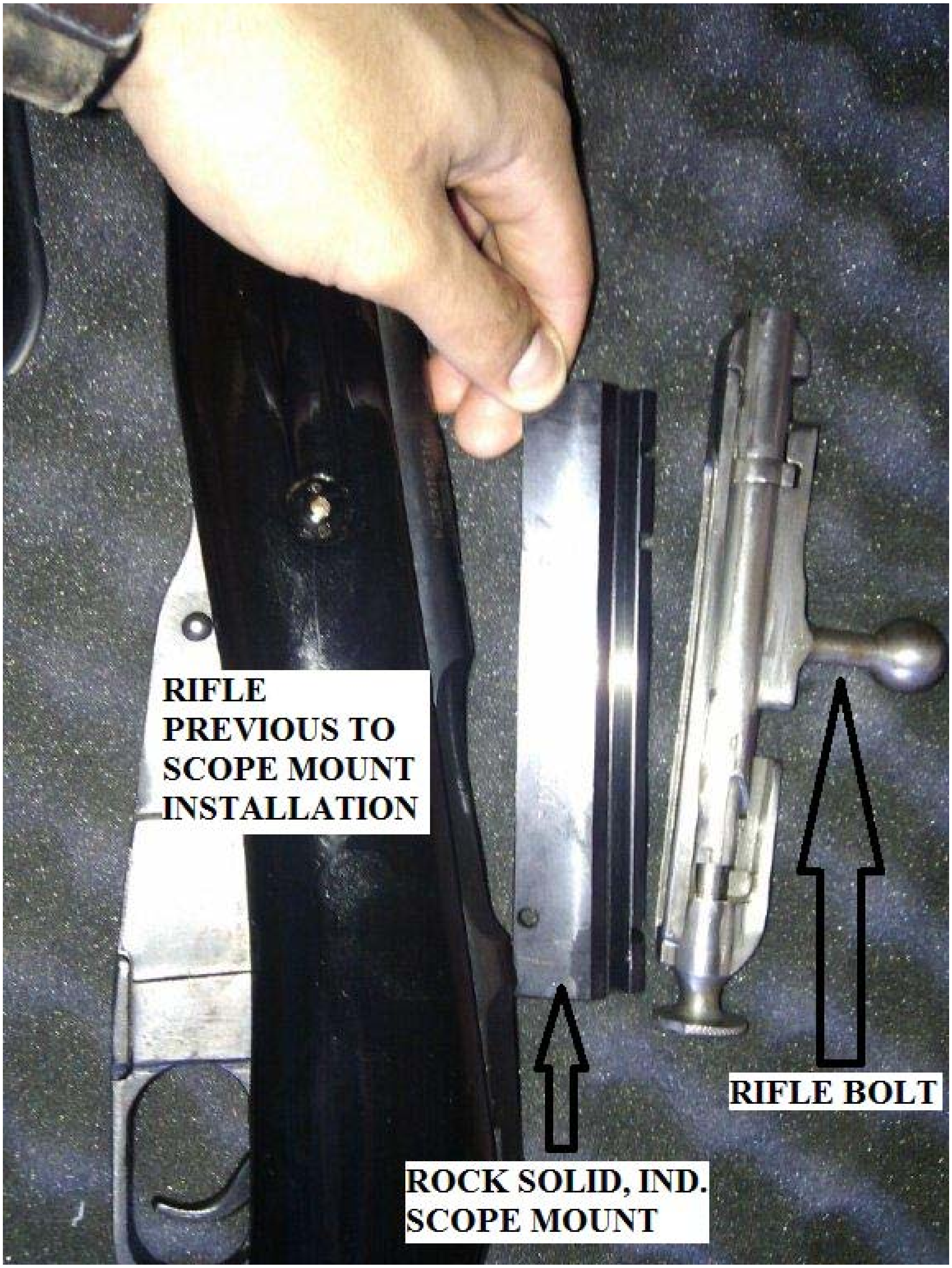


Figure 6: Scope Mount Installation allows the reader to view the rifle previous to implementation of the Rock Solid Industries Scope Mount.

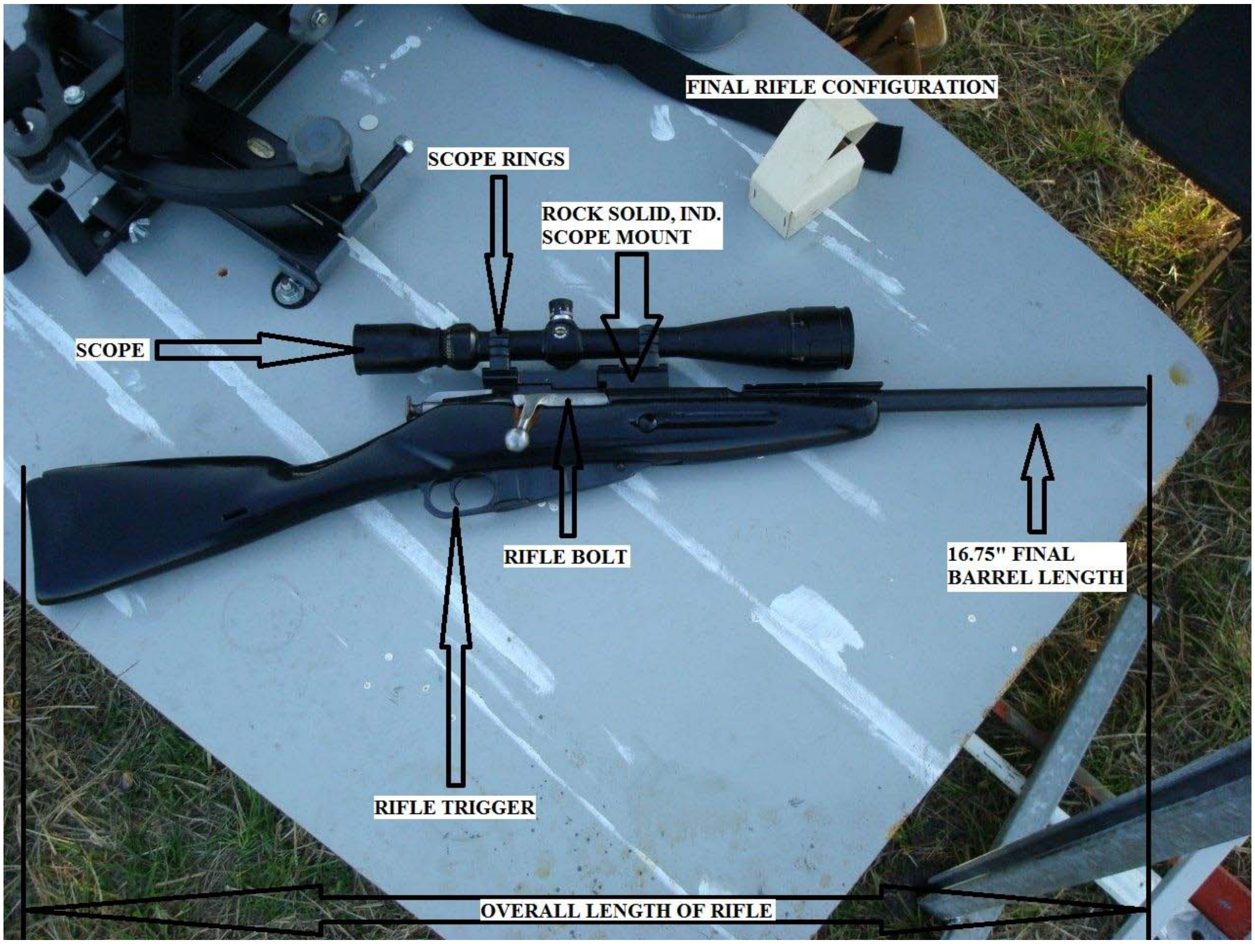


Figure 7: Final Rifle Configuration allows the reader to view the final result of the barrel cutting procedures, producing a final barrel length of 16.75 inches. Figure 11 also allows the reader to see how the overall length of the rifle is defined.

Variability within ammunition plays a large role in the precision capabilities of a firearm; match grade ammunition is usually specified for highest consistency in testing conditions. Match grade ammunition can be defined as ammunition which is manufactured with low tolerances to produce rounds that consistently perform to high standards imposed by the manufacturer. These match grade rounds would allow the shooter to maintain a higher degree of repeatability between shots, with repeatability being the paramount influence to rifle precision. Match grade ammunition, however, was unrealistic in our particular experiment due to its high cost. Instead, military grade surplus rounds were used, with more experimental shots taken, helping to produce a mean velocity and reduce variations through a larger sample size.

PROCEDURES

Throughout the experimental testing, various procedures were required to provide consistent results. Without implementing these procedures, one iteration would have an effect on the next, and work to invalidate the testing results. The experiment began with an initial barrel length measurement, followed by a crowning/lapping of the muzzle, cleaning of the rifle barrel, and finally the shooting procedure. After the testing of the virgin barrel length, the sequences of procedures were as follows: 1) Barrel Length Measurement, 2) Cutting Procedure, 3) Rifle Cleaning, 4) Shooting Procedure, which were then repeated for each iteration until reaching the final barrel length. These procedures are presented below.

Barrel Length Measurement

The procedure regarding the measurement of the rifle barrel length was as follows. First, the bolt was opened, and the firearm was inspected to ensure it was UNLOADED. Second, the bolt was closed and a measurement rod inserted into the barrel until it contacted with the closed bolt face. Third, the measurement rod was held at this location and marked with a permanent marker at the location of protrusion from the muzzle. Fourth, the rod was removed and measured from the inserted end to the mark to determine the barrel length. This procedure is correct and up to date with current Bureau of Alcohol, Tobacco and Firearms regulations. It should be noted that the measurement rod should have a diameter no greater than the smallest diameter provided by the rifling, as it will not fit. Furthermore it is imperative that this measurement rod not be too small in diameter as to provide an unrealistic barrel length measurement due to excessive tolerances. Thus, the measurement rod should be as large as possible while still allowing insertion within the muzzle.

Cutting Procedure

First the original barrel length was measured and recorded (28.75 inches). Previous to cutting the virgin barrel and performing the initial length tests, the virgin barrel received the same muzzle crowning and lapping procedure given to all of the other barrel length iterations. This was done to ensure a proper baseline was provided and to improve consistencies between barrel length iterations. Crowning was required subsequent to barrel cutting, as “any barrel’s muzzle must be properly crowned… so there’s not the tiniest possible binding or disrupting the bullet as it exits the barrel” [12 pg. 39, ultimate sniper]. In other words, a crowning process was required to provide consistent muzzle geometries, aiding testing consistency, by ensuring each barrel length iteration used the exact crown as all of the others.

From here, two inches from the muzzle of the rifle was measured and marked with a scribe. A small bore cleaning cloth was then inserted about 4 inches deep into the muzzle to collect the chips and debris incurred in the barrel cutting. The rifle was then taken to the chop saw and fixed in a vise for initial cutting, as seen in Figure 8 located on the following page. After the two inch section had been cut, a hand file was used in order to square the muzzle and remove any residual chips from the cutting process. After the muzzle was squared, the hand file was used around the outer radius of the muzzle to implement a slight chamfer.

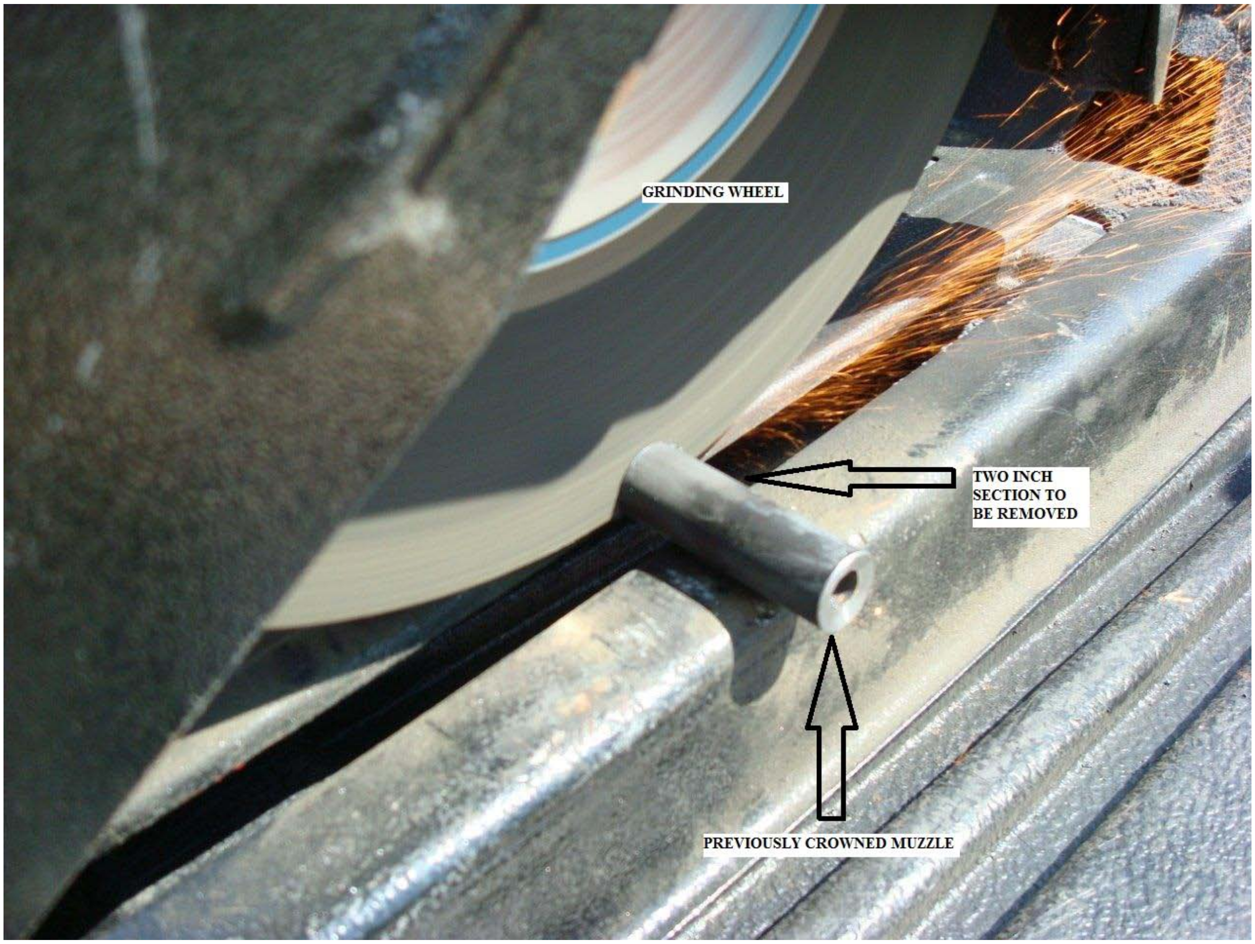


Figure 8: Cutting Operation allows the reader to visualize the barrel cutting procedure, as a two inch section is removed in order to proceed to the next barrel length iteration.

From here, the muzzle crowning tool was oiled and inserted with the .30 caliber precision pilot residing within the bore of the rifle. The muzzle crowning tool was then spun by hand drill until a uniform crown was cut, as seen in Figure 9 located on the following page. It should be noted that this muzzle crowning procedure was performed with the rifle barrel fixed vertically. It is imperative that the barrel be fixed vertically for this muzzle crowning procedure, should it be done by hand; this is to ensure that the muzzle crowning tool properly centers itself. If the rifle had been horizontally fixed, gravity would allow the tool to remove more from the bottom than the top of the muzzle.

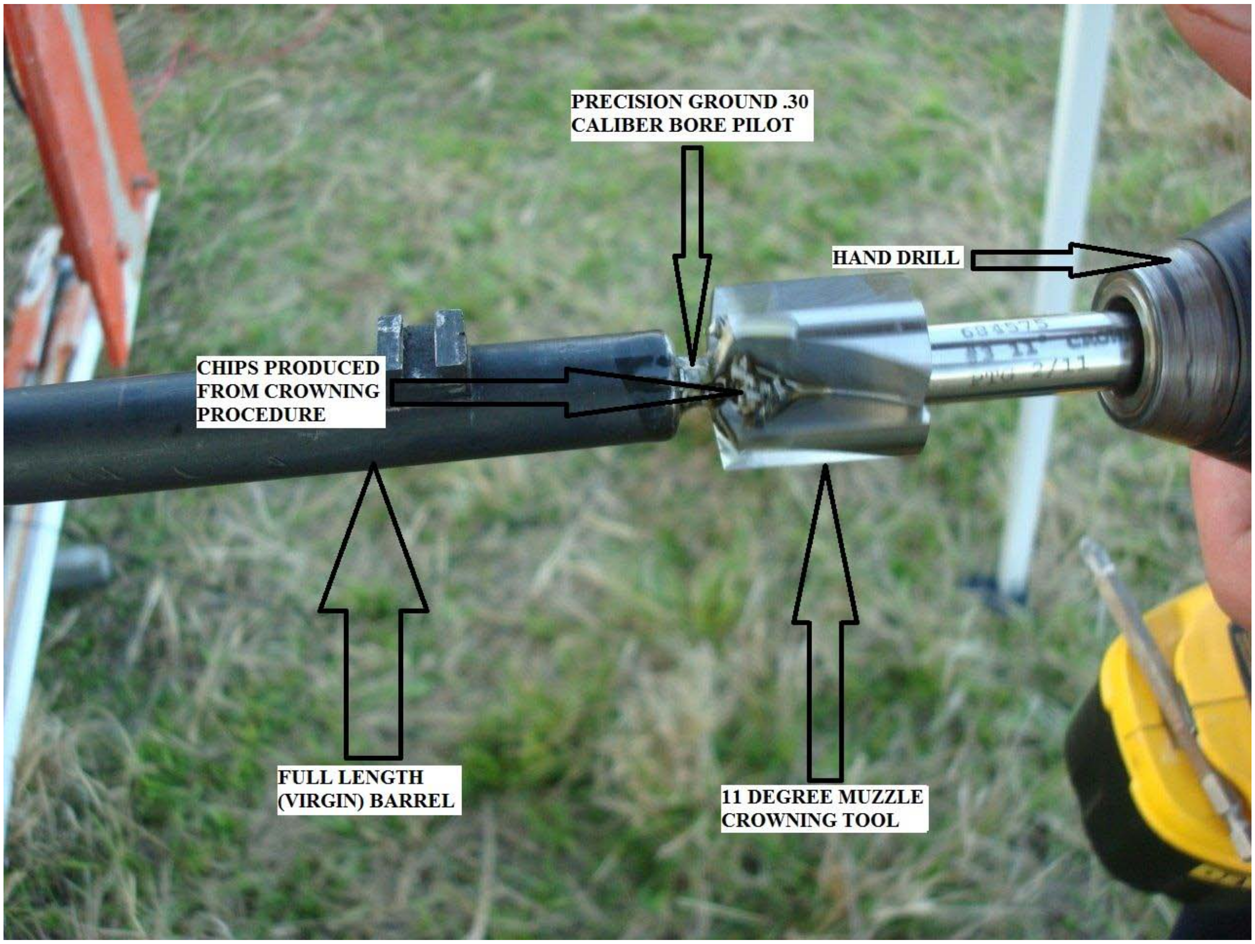
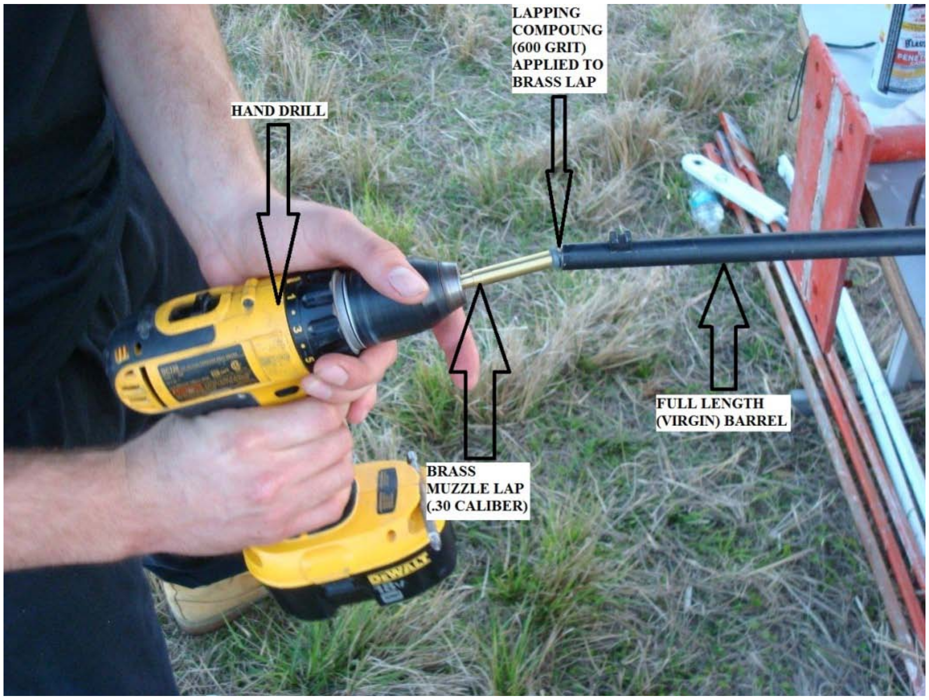
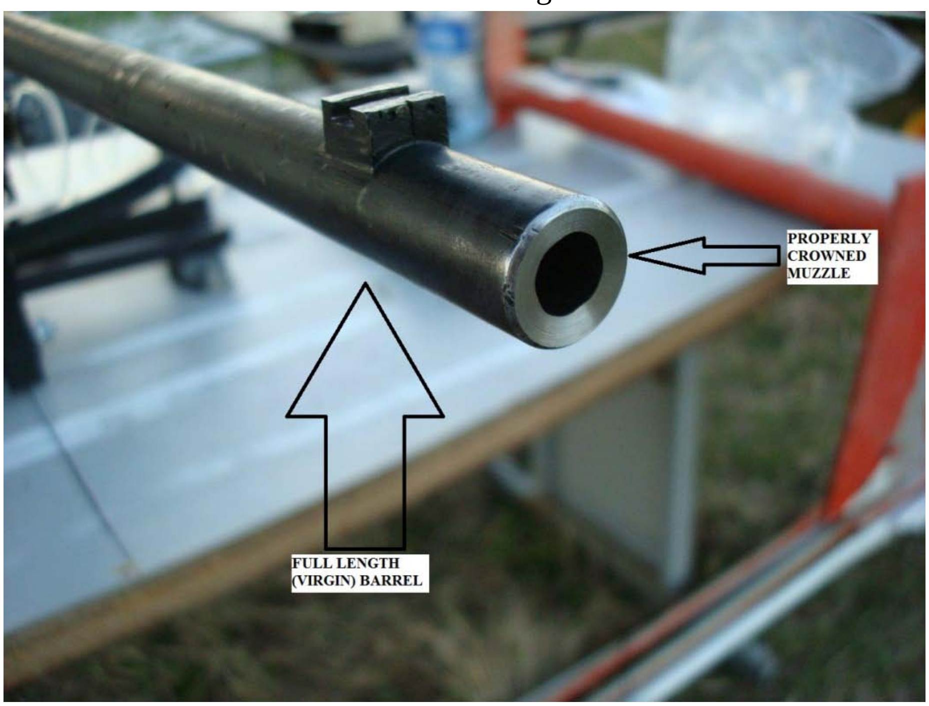


Figure 9: Crowning Operation allows the reader to visualize the crowning tool which was used to implement an 11 degree target crown on each barrel length tested. Figure 7 also allows the reader to visualize the production of chips which results from the cutting procedure and why the barrel must be cleaned before the start of the next test iteration.

After the uniform crown was cut, the muzzle crowning tool was removed and a brass muzzle lap (for .30 caliber use) was inserted into the hand drill. From here the brass lap was coated with a layer of 600 grit lapping compound and subsequently inserted into the face of the muzzle. The brass lap is slightly oversized and designed to be spun by the hand drill while also rotating the drill around the muzzle with the drilling hand, as shown in Figure 10. This effectively removes any burrs which may still reside in the muzzle crown and assures that it is smooth and uniform. A finished muzzle may be viewed in Figure 11. Both Figures 10 and 11 are represented on the following page



<u>Figure 10: Muzzle Lapping Operation</u> allows the reader to view the procedure regarding the lapping of the crowned barrel. This procedure is required to ensure no burrs exist on the prepared muzzle crown and to ensure each barrel length is consistent with the others.



<u>Figure 11: Finished Muzzle</u> allows the reader to see how each muzzle appeared at the end of the cutting procedure. In viewing Figure 9, the reader may see the 11 degree target crown and its smooth and uniform appearance, resulting from crowning and lapping of the virgin barrel.

From here, the cleaning rod is inserted from the bolt side of the rifle towards the muzzle in order to push out the cleaning cloth and the chips formed during the cutting, facing, and lapping procedures.

Rifle Cleaning

The rifle was cleaned multiple times throughout the testing in order to provide a clean bore for the beginning of each barrel length testing iteration. The cleaning procedure began by removing the bolt from the rifle, and checking to make sure the rifle was unloaded. From here the cleaning tool rod was fitted with a .30 caliber bore brush and this brush was coated in a bore cleaning solvent. After coating the brush, it was inserted from the muzzle end into the bore, and brushed up and down the length of the bore a few times. After brushing, a cleaning patch was passed down the bore to remove the residual bore solvents and grit as well as prepare the bore for a light lubrication. After the first cleaning patch was removed, it was replaced with another fresh patch, coated lightly in oil. This patch was passed down the bore and removed, summing up the cleaning procedure.

Shooting Procedure

Previous to sending any bullets down range, it was first necessary to strap the rifle to the gun bench, and connect the remote trigger syringe assembly. From here, the scope caps were removed for viewing, and ammunition was procured for testing. Previous to loading of the firearm, velocity and sound acquisition devices, as well as ear plugs were checked.

The shooting procedure begins by opening the bolt of the rifle, inserting a cartridge, closing the bolt and sighting the rifle to the target. Care and patience were required to sight the rifle to the exact point of aim per shot, per iteration. After proper sighting took place, the syringe was slowly compressed, in turn slowly pushing the trigger of the firearm remotely. After the trigger was completely compressed, the shot was fired, and its point of impact was assessed with a set of binoculars. After the point of aim had been confirmed, the velocity as well as sound measurements were checked to make sure they were recorded correctly. From here the bolt was opened, the spent case extracted, and the procedure repeated for the following nine shots of the iteration.

RESULTS:

Velocity vs. Barrel Length Results

Velocity versus barrel length was measured in two inch intervals from an initial barrel length of 28.75” to a final barrel length of 16.75”. This allotted seven data points for curve fitting, with the respective barrel lengths measured at 28.75, 26.75, 24.75, 22.75, 20.75, 18.75, and 16.75 inches. Ten shots were taken at each barrel length, with statistical analysis performed at the conclusion of each shot string. The average velocity of the Mosin-Nagant rifle varied from a maximum average velocity of 2827 (Ft/Sec) at full length to a minimum average velocity of 2521 (Ft/Sec) at minimal length. Together this yielded a reduction of 306 (Ft/Sec) in average velocity from the full length to minimal length transition.

After compilation of the velocity data, the average velocity of each barrel length iteration was extracted and plotted in relation to the barrel length. From here a linear curve was fit onto the data points, yielding a coefficient of determination (R^2 Value) of over 99 percent. The significance of this value may be expressed in Layman’s terms as “The Linear Curve fit onto the Velocity vs. Barrel Length data may accurately describe the data points within 99 % accuracy” or even further simplified as “The Velocity vs. Barrel Length data is inherently linear”. The average velocity difference per inch of barrel length (slope of the line) was 25.658 (Ft/Sec), or 51.316 (Ft/Sec) per barrel length iteration (2 inch cut).

The significance of the high coefficient of determination is that it allows a linearity assumption in relation to the average velocity vs. the barrel length. Had the coefficient of determination been lower, it is quite possible that no conclusions may have been drawn. For example, if the coefficient of determination was low for a linear curve fitted line, we would then have to look towards fitting the data with an exponential, a logarithmic, or a polynomial type curve. One dilemma often encountered with a polynomial type curve interpolation, is selecting the order of polynomial to fit to your data. In one aspect, the higher the polynomial order the higher accuracy you may have by allowing your curve to utilize more data points in your interpolation. This is a bittersweet method, as witnessed in Runge’s Phenomenon when using interpolation with high order polynomials, as oscillation is witnessed near the intervals of the data [13]. Ultimately, if the coefficient of determination was lower, it’s possible that more data points would be required to draw any conclusions to the average velocity vs. barrel length trend.

The quantitative results of the velocity measurements are reproduced on the next page.

Table 1: Overall Velocity vs. Barrel Length Testing Results represents each barrel length test, and the associated statistical quantifiers for that specific test. Test #1 pertains to the baseline testing, or the testing of the virgin barrel length. Each successive test removed 2 inches from the barrel, reaching Test #7, which tested the final barrel length of 16.75 inches.

	Maximum Velocity (ft/s)	Minimum Velocity (ft/s)	Average Velocity (ft/s)	Range (ft/s)	Standard Deviation (ft/s)	Median Velocity (ft/s)
Test #1	2879	2766	2827	113	39	2845.5
Test #2	2836	2749	2778	87	27	2771.5
Test #3	2772	2704	2751	68	20	2754
Test #4	2743	2650	2698	93	30	2710
Test #5	2710	2599	2632	111	32	2625.5
Test #6	2614	2539	2578	75	22	2583
Test #7	2574	2469	2521	105	38	2524.5

Table 2: Full Length Barrel (28.75”) represents the ten shots fired at the virgin barrel length, used in the establishment of a proper baseline; zero inches net reduction

Shot Number	Shot Velocity (ft/s)	Shot Energy (ft*Lbs.)	Power Factor (grains*ft/sec)
1	2766	2497.027	406.602
2	2849	2649.134	418.803
3	2855	2660.303	419.685
4	2849	2649.134	418.803
5	2766	2497.027	406.602
6	2879	2705.218	423.213
7	2795	2549.662	410.865
8	2842	2636.132	417.774
9	2818	2591.797	414.246
10	2855	2660.303	419.685

Table 3: Two Inch Barrel Length Reduction (26.75") represents the ten shots fired at the first barrel length iteration; two inches net reduction

Shot Number	Shot Velocity (ft/s)	Shot Energy (ft/s)	Power Factor (grains*ft/sec)
1	2783	2527.815	409.101
2	2754	2475.408	404.838
3	2754	2475.408	404.838
4	2766	2497.027	406.602
5	2807	2571.602	412.629
6	2766	2497.027	406.602
7	2749	2466.428	404.103
8	2836	2625.013	416.892
9	2777	2516.928	408.219
10	2789	2538.727	409.983

Table 4: Four Inch Barrel Length Reduction (24.75") represents the ten shots fired at the second barrel length iteration; four inches net reduction

Shot Number	Shot Velocity (ft/s)	Shot Energy (ft/s)	Power Factor (grains*ft/sec)
1	2754	2475.408	404.838
2	2772	2507.872	407.484
3	2704	2386.34	397.488
4	2772	2507.872	407.484
5	2737	2444.942	402.339
6	2754	2475.408	404.838
7	2754	2475.408	404.838
8	2743	2455.673	403.221
9	2760	2486.206	405.72
10	2766	2497.027	406.602

Table 5: Six Inch Barrel Length Reduction (22.75") represents the ten shots fired at the third barrel length iteration; six inches net reduction

Shot Number	Shot Velocity (ft/s)	Shot Energy (ft/s)	Power Factor (grains*ft/sec)
1	2721	2416.44	399.987
2	2656	2302.37	390.432
3	2650	2291.979	389.55
4	2704	2386.34	397.488
5	2715	2405.795	399.105
6	2743	2455.673	403.221
7	2710	2396.942	398.37
8	2666	2319.74	391.902
9	2710	2396.942	398.37
10	2710	2396.942	398.37

Table 6: Eight Inch Barrel Length Reduction (20.75") represents the ten shots fired at the fourth barrel length iteration; eight inches net reduction

Shot Number	Shot Velocity (ft/s)	Shot Energy (ft/s)	Power Factor (grains*ft/sec)
1	2629	2255.798	386.463
2	2624	2247.225	385.728
3	2650	2291.979	389.55
4	2599	2204.609	382.053
5	2645	2283.339	388.815
6	2710	2396.942	398.37
7	2604	2213.099	382.788
8	2614	2230.13	384.258
9	2645	2283.339	388.815
10	2604	2213.099	382.788

Table 7: Ten Inch Barrel Length Reduction (18.75") represents the ten shots fired at the fifth barrel length iteration; ten inches net reduction

Shot Number	Shot Velocity (ft/s)	Shot Energy (ft/s)	Power Factor (grains*ft/sec)
1	2594	2196.134	381.318
2	2559	2137.271	376.173
3	2559	2137.271	376.173
4	2583	2177.548	379.701
5	2614	2230.13	384.258
6	2583	2177.548	379.701
7	2569	2154.007	377.643
8	2588	2185.987	380.436
9	2539	2103.993	373.233
10	2599	2204.609	382.053

Table 8: Twelve Inch Barrel Length Reduction (16.75") represents the ten shots fired at the sixth barrel length iteration; four inches net reduction

Shot Number	Shot Velocity (ft/s)	Shot Energy (ft/s)	Power Factor (grains*ft/sec)
1	2569	2154.007	377.643
2	2554	2128.927	375.438
3	2574	2162.4	378.378
4	2539	2103.993	373.233
5	2539	2103.993	373.233
6	2496	2033.331	366.912
7	2473	1996.031	363.531
8	2492	2026.819	366.324
9	2469	1989.579	362.943
10	2510	2056.205	368.97

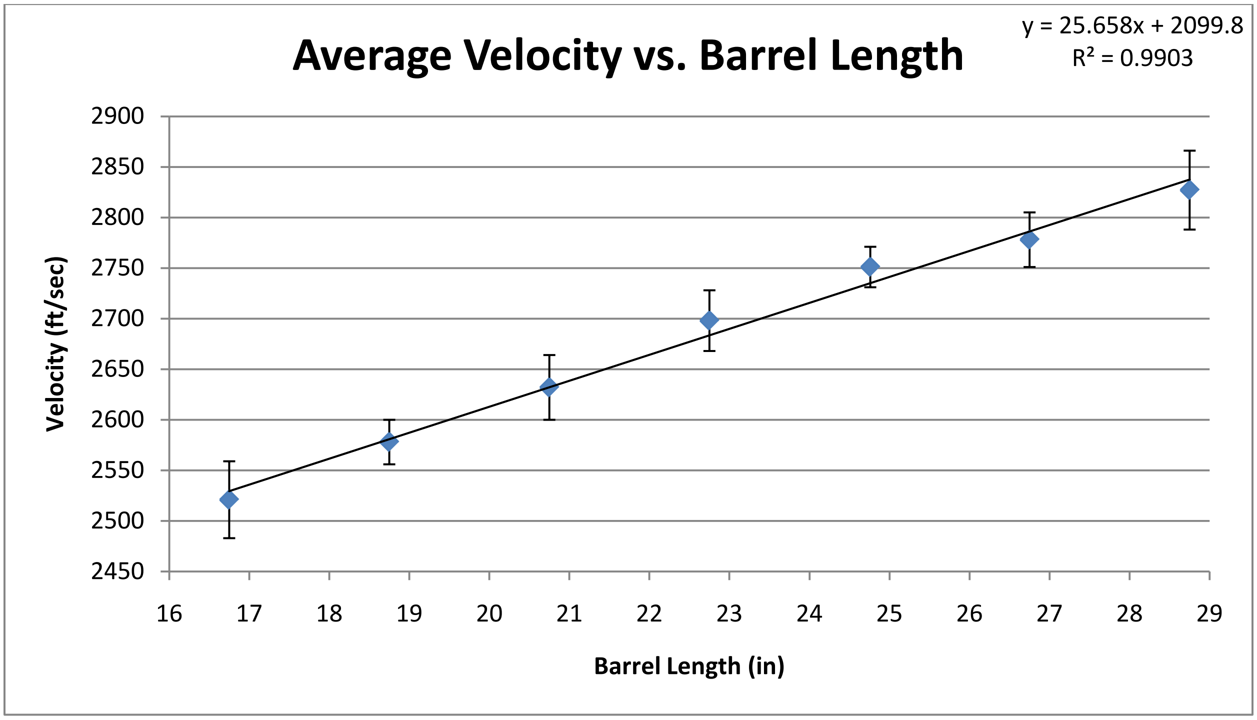


Figure 12: Average Velocity vs. Barrel Length shows the average velocity of each barrel length tested in relation to the barrel length of that specific test. As it may be seen, the highest velocity was witnessed with the virgin length barrel, with a linearly decreasing velocity towards the lowest velocity witnessed with the shortest barrel length. A linear trend line was passed through the data points, with the respective trend line equation and coefficient of determination (R^2) value posted in the top right of the figure. This trend line accurately describes the data within 99.03%. The error bars vertically extending from the data points represent a single standard deviation of error, relative to the standard deviation witnessed in the test results per each barrel length test. These specific standard deviation values may be found in Table 1.

Report vs. Barrel Length Results

The report characteristics of each barrel length were measured in order to analyze the variances occurring with increased reductions in regard to the barrel length of the rifle. Unfortunately microphone saturation occurred as the barrel length was reduced. This saturation effect would no longer allow a quantitative analysis of barrel lengths to be analyzed from one iteration to another. The visual characteristics pertaining to the rise and decay of the signal were still able to be analyzed visually, with the exception of the peak(s) which were lost under saturation. These visual report results are produced below.

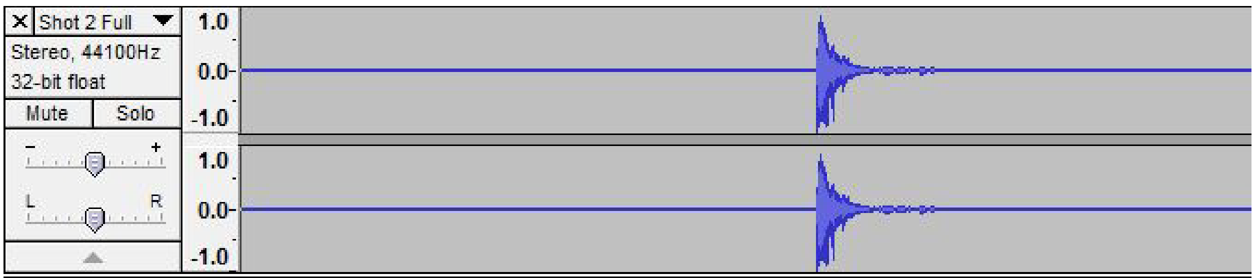


Figure 13: Report of Full Length Barrel (28.75")

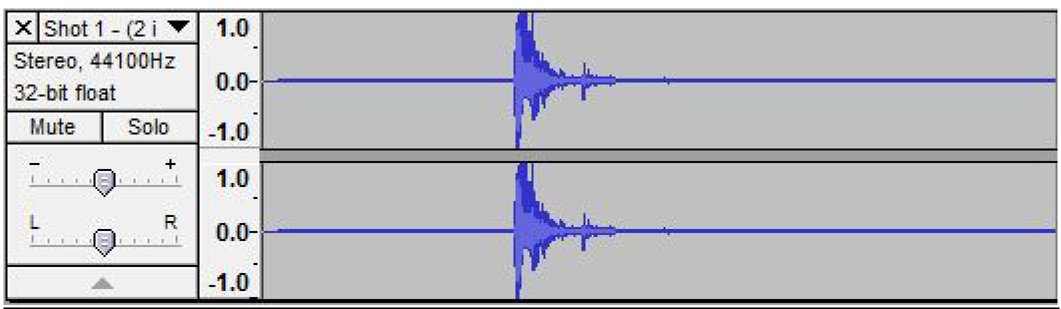


Figure 14: Report of Two Inch Barrel Length Reduction (26.75")

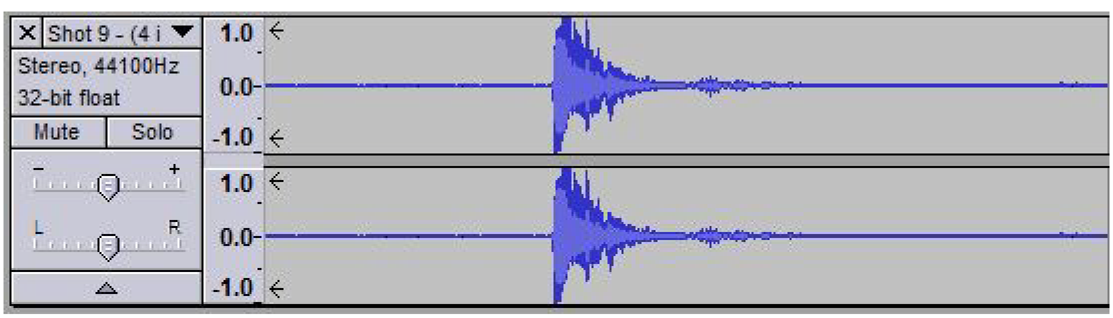


Figure 15: Report of Four Inch Barrel Length Reduction (24.75")

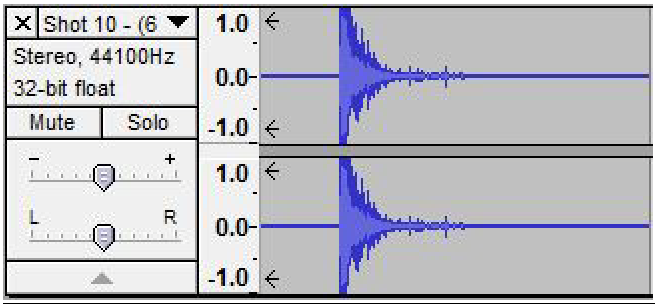


Figure 16: Report of Six Inch Barrel Length Reduction (22.75")

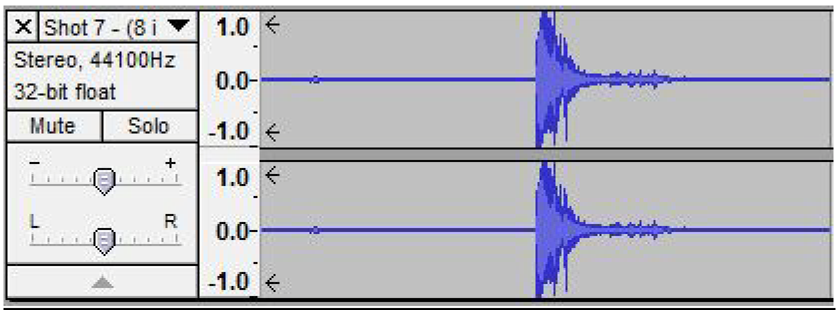


Figure 17: Report of Eight Inch Barrel Length Reduction (20.75")

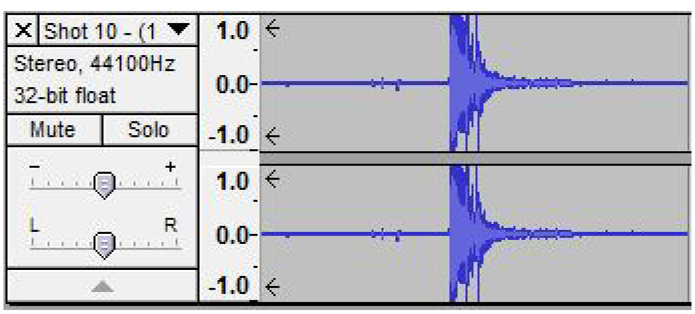


Figure 18: Report of Ten Inch Barrel Length Reduction (18.75")

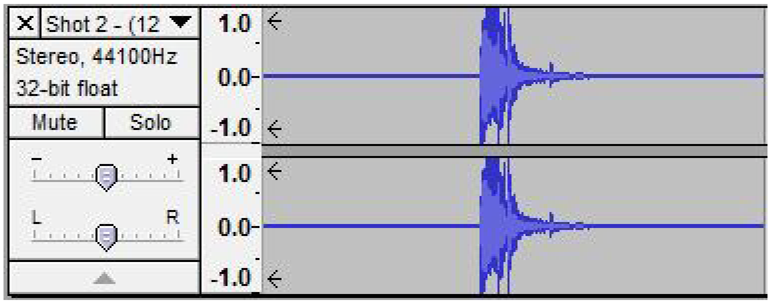


Figure 19: Report of Twelve Inch Barrel Length Reduction (16.75")

Precision vs. Barrel Length Results

The precision characteristic of the Mosin-Nagant rifle in comparison to the length of its barrel was a desired result within in this experiment. 10 Shots per barrel length iteration were fired from the gun bench to a target located 100 yards away. It was desired to see if any relation may be formed as to the shot groupings increasing or decreasing as successive cuts were made to the barrel. Unfortunately upon analysis of the target groupings, no implications were able to be made towards saying the precision increased or decreased as the barrel was reduced in length. Each barrel length iteration held a similar amount of variance, and the target results are reproduced for visual inspection on the following pages.

Figure 20: Target Pertaining to the Full Length Barrel (28.75”)

Figure 21: Target Pertaining to the Two Inch Reduction (26.75”)

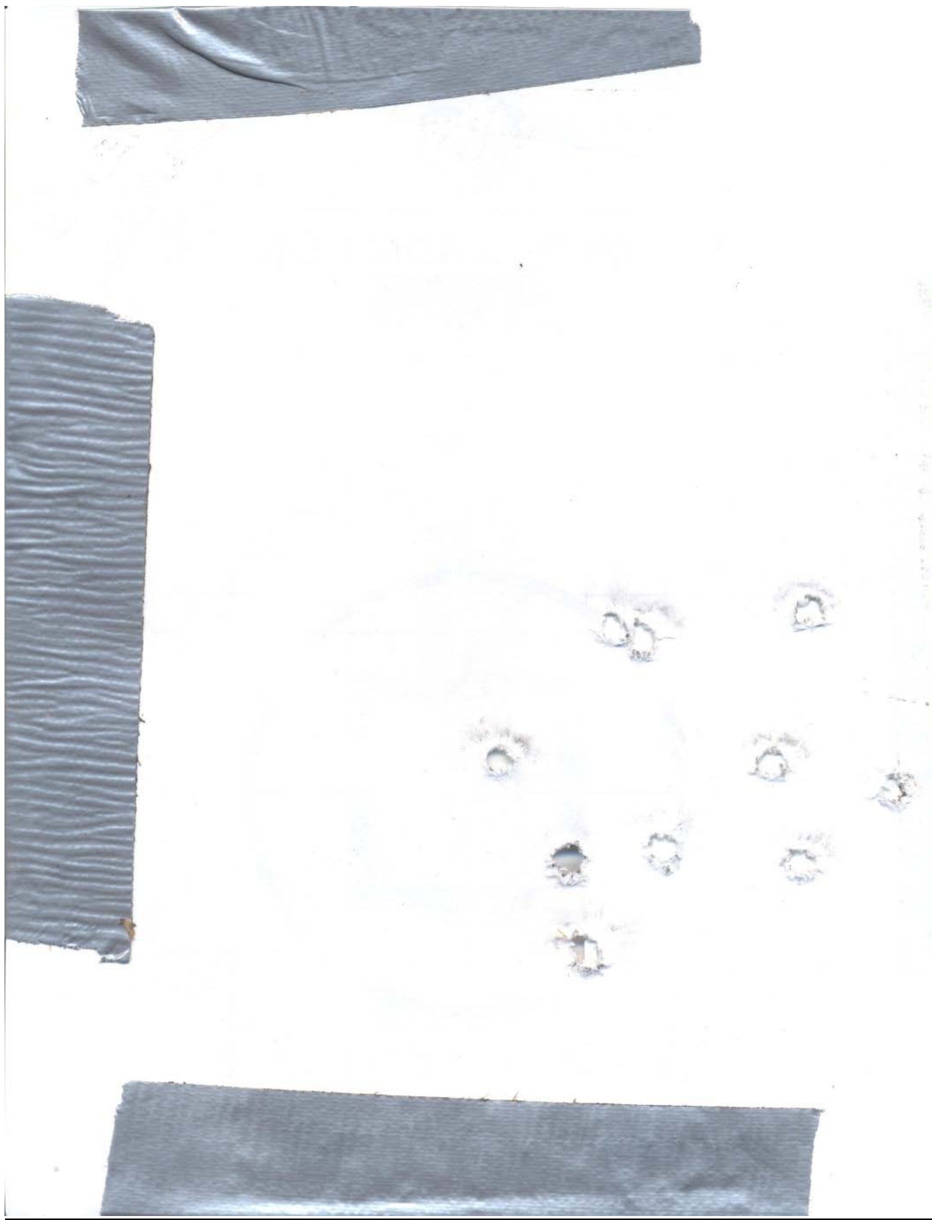


Figure 22: Target Pertaining to the Four Inch Reduction (24.75”)

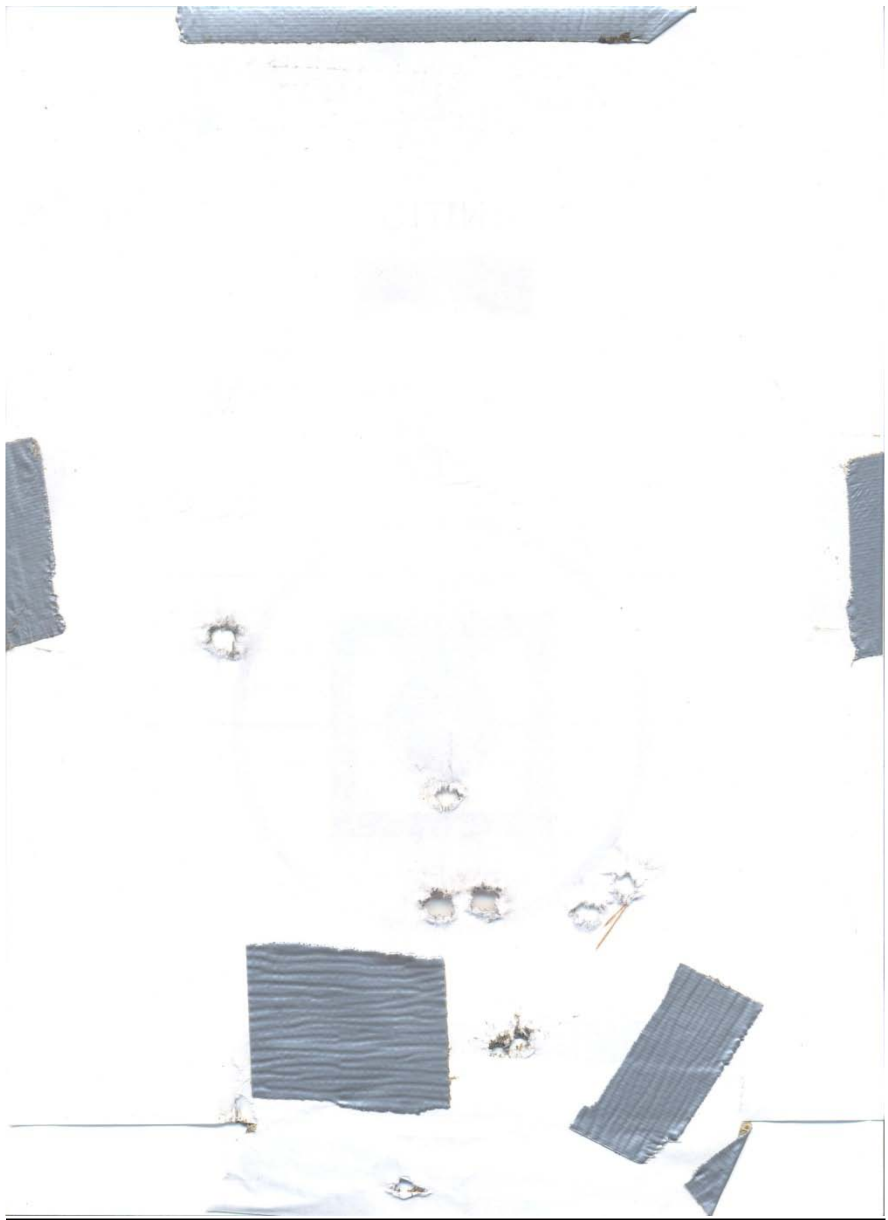


Figure 23: Target Pertaining to the Six Inch Reduction (22.75”)

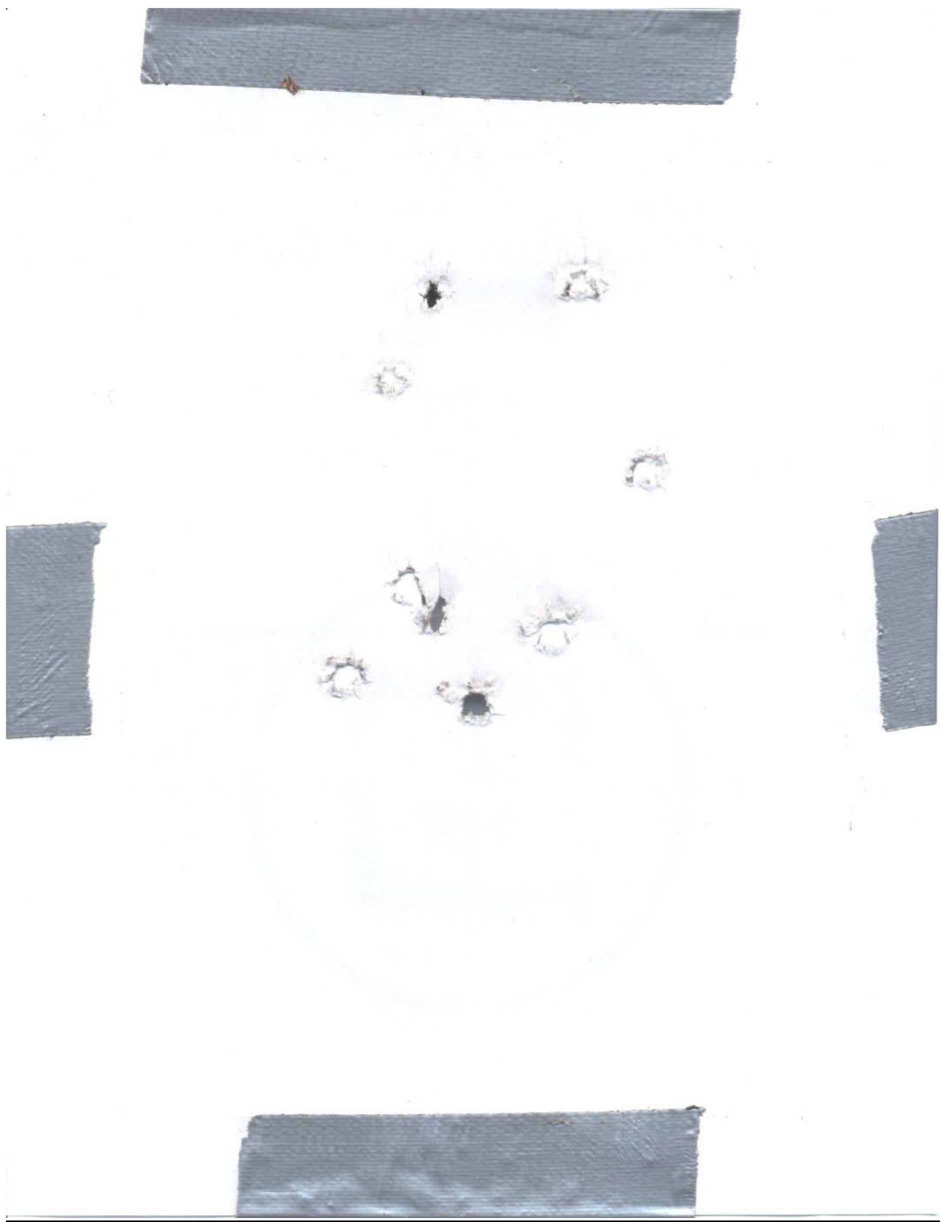


Figure 24: Target Pertaining to the Eight Inch Reduction (20.75”)

Figure 25: Target Pertaining to the Ten Inch Reduction (18.75")

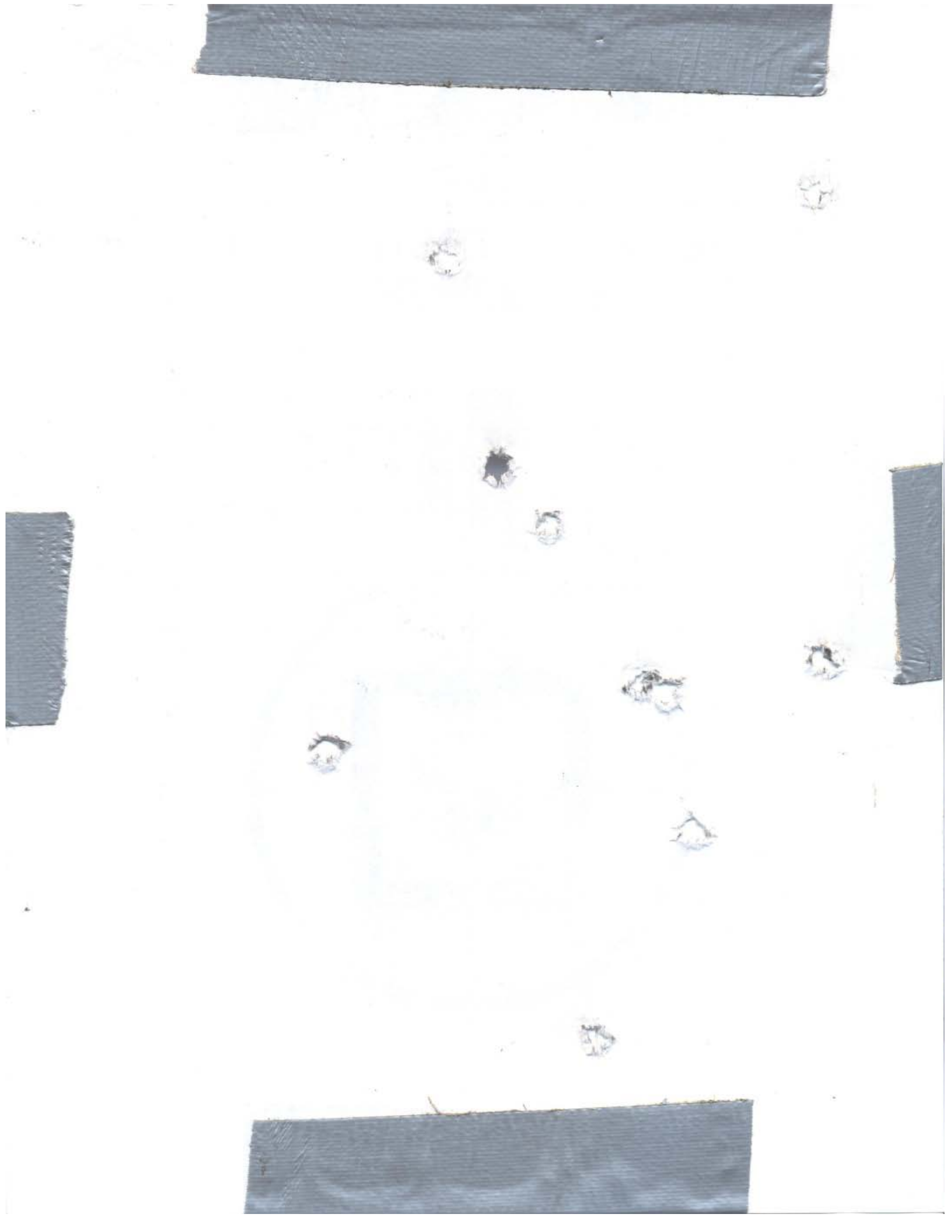


Figure 26: Target Pertaining to the Twelve Inch Reduction (16.75”)

DISCUSSION:

Why?

This specific topic was chosen for a number of reasons: One, due to the lack of information available on the actual effects of barrel length, it appeared interesting to produce new results in this area. Seeing that many people appear to believe that the only thing responsible for accuracy was a long barrel, it was hoped that this experiment could educate others to the facts. Second, with the high flux of surplus rifles in the American market, many bargain hunters will purchase a surplus military rifle and “sporterize” the rifle to their own specifications. A sporterization often involves some degree of barrel length reduction, in order to make the surplus rifles more adaptable to the hunter and his/her environment. This is often where the barrel length debate comes into play, as far as which barrel length is optimal, and currently available data is mostly biased and qualitative. By analyzing the velocity, report, and precision differences of the rifle in relation to its barrel length, unbiased quantitative data may be passed onto the gunsmith, allowing him/her to modify their rifle to their own specific wants/needs in which they determine. Finally, with the low cost associated with the Mosin Nagant, military ammunition and its long barrel, testing may be performed with multiple barrel lengths, hopefully aiding in a conclusion to the barrel length debate.

Velocity vs. Barrel Length

The velocity vs. barrel length data recordings were a success, with no problems occurring during testing in regards to the digital chronograph. All shots were recorded, and the various statistical quantifiers calculated. The velocity data was exported from the PC Remote program (included with the digital chronograph hookup kit) to various Excel spreadsheets. After grouping each barrel length iteration’s average and median velocities, the next step was to analyze the variation characteristics of the velocities vs. barrel length.

First the average velocity vs. barrel length was plotted for all tested lengths, which showed a very high R^2 (coefficient of determination) value of 99.03%, when curve fit with a linear equation. Although this was a more than acceptable value, it was also chosen to plot the median velocity vs. barrel length, to see if any further conclusions may be drawn. The median velocity vs. barrel length returned an R^2 value of 98.41%; while still a very acceptable value for curve fitting and proper data explanation, the average velocity still proved to be a better choice for the creation of a function describing velocity vs. barrel length. The significance of both of these high coefficients of determination, however, allows us to verify the velocity variations versus barrel length as being ***truly*** linear.

If legalities would have allowed, the experiment would have gone to shorter barrel lengths, allotting more data points and allowing further velocity analysis to be extracted. This simply wasn’t plausible with the current federal regulations, although similar testing has been performed with pistols, where such barrel length regulations don’t currently exist. [14]

Variances between shots in each barrel length iteration could have been explained by a number of reasons. The major factor resulting in varied test results could be attributed to the use of surplus military ammunition. While the difference in military grade surplus ammunition and match grade ammunition wasn't the focal point of the study, they surely would play a role in testing variability. Match grade ammunition would provide more consistent velocities from round to round, however it is currently unclear how much variability may be reduced. Another consideration would be the velocity differences incurred as the barrel was heated. These would lead to generally higher velocities witnessed as the barrel heats and expands. Lastly, the sealant provided to the projectile and case neck (characteristic of the military rounds), has been shown to unevenly release the bullet, negatively affecting consistency pertaining to velocity and accuracy [15].

Report vs. Barrel Length

The report vs. barrel length data was not able to be analyzed in any quantitative form. This was due to the microphone's placement in relation to the rifle. Originally the microphone distance was calibrated by firing the original length rifle, and placing the microphone in a location where microphone saturation wouldn't occur. This was adequate for the first set of tests, but quickly became worthless as the microphone became saturated with further barrel length reductions. This could have been avoided, assuming the microphone would have been placed in a location sufficient for complete testing of all the barrel lengths, without any saturation of the microphone. In hindsight, this effect should have been considered, and the microphone placed further from the rifle. The saturation effects were realized almost immediately following the original length tests, however, at that point, the microphone distance was unable to be changed in order to maintain consistency between iterations.

Since the report data proved inconsistent from a quantitative point of view, rather than scrap it all together, it was chosen to analyze the *quality* of the sound from cut to cut. In other words, while a numerical analysis of the rifle's report in relation to the barrel length was unobtainable due to saturation occurring in the data acquisition, a qualitative analysis was still sufficient in relating the report differences vs. barrel length. From a qualitative viewpoint, the report appears to increase in rise, and also increase in decay, as the barrel length is shortened. That is, the original barrel length produces a waveform which has a moderate rise and decay, with a magnitude preceding microphone saturation. As the barrel length decreases in length (as testing progressed), the waveform magnitude increased. The rise of the waveform also appears much sharper as testing continued, quickly rising past the saturation point and decaying in a quicker, less consistent manner.

It is of worth noting, that the muzzle blast also grew as the barrel length was decreased. Unfortunately, no pictures were taken in relation to the muzzle blast visually produced per shot, or per barrel length iteration. Qualitatively speaking, however, the virgin barrel length would not provide a visually distinct muzzle blast when fired. Often, if firing took place during dusk or dark conditions, a small flame was noticed to protrude from the muzzle, but often went unnoticed. As the barrel length decreased, audibly the differences became clear (even with earplugs). The report didn't appear to become audibly intimidating until the final barrel cuts, most notably in the 18.75" and 16.75" barrel lengths. The muzzle blast also became quite intimidating at these lengths, no longer able to go unnoticed, whether firing in light or dark conditions.

Thus, theories and written data presented previously were verified in terms of the report and muzzle blast increasing as the barrel length decreases. These theories were not, however, analyzed in any numerical fashion, which would have been desired. Future testing, in which proper care would be taken to avoid microphone saturation, would allow quantitative analysis to be performed.

Precision vs. Barrel Length

The experiment was unsuccessful in providing any data or means to relate the precision capabilities of the rifle to the length of its barrel. This was disappointing, but not surprising given the many parameters affecting precision and ultimately firearm accuracy.

Many of the considerations made in developing the testing conditions, were with the intentions of reducing as many experimental and user variations as possible, in the hopes that the precision of the rifle may be determined.

The problem with precision measurement (and ultimately accuracy measurement) is the inability to effectively and solely test precision characteristics, without having other factors altering the testing.

Even though differences in the precision of the rifle weren't able to be explained in this experiment, if performed again, a different procedure would surely be implemented in the hopes of allowing quantitative precision measurements to be made.

One of the largest complaints was the gun bench. Originally the gun bench was chosen in order to eliminate the most user error possible. This reduction in user error continued with the implementation of the remote trigger device. These modifications turned out to backfire, as the gun bench was poorly engineered. For one, the play existing within the sliders and construction of the gun bench was a problem. The undue amount of play allowed the rifle to shift around in relation to the table, even though it was secured with straps to the bench itself.

Another large complaint on behalf of the gun bench was the poor choice of bolt lead as well as the overall design of the evaluation screws. The evaluation adjustments consisted of two knobs located on each side of the rifle which essentially acted as a lead screw and allowed the rifle to rise in relation to the gun bench. This would have been sufficient, IF, a proper lead was selected for the adjustment lead screws, and if the screws were centered on a point, which they were not.

The leads of the adjustment screws were so coarse; it's incomprehensible how anyone could have thought them acceptable for precision adjustments. Not only were the leads too coarse for precise aim modifications, but they were also too coarse to prevent undesired back driving and easily back drove themselves under recoil, constantly requiring modifications. The second downside was that these lead screws were centered on a nut, as opposed to a point. This provided inconsistent vertical movement, instead producing a vertical motion that "wobbled" around.

CONCLUSION:

The projectile velocity was shown to vary ***linearly*** as barrel length reductions continued. Thus, shooters looking to exploit the maximum velocity potential from their rifle should leave the original barrel length untouched. Other shooters, who may appreciate a shorter barrel over the benefit of increased projectile velocities, can look at the tables provided in the results section to select a barrel length which satisfies their needs. Furthermore, if a shooter chooses to implement a barrel length which is different from the lengths tested in this experiment; they may use the linear trend line function from the Average Velocity vs. Barrel Length figure, and simulate an average velocity for their specific length. These results obviously pertain to the Mosin-Nagant rifle in particular, but may be assumed applicable for similarly powered rifles. Never forget to ensure your modifications are legal under current laws and regulations, as these vary with time and location.

While the report variations of the rifle weren't able to be produced in a quantitatively based fashion, the report was shown to increase as the barrel length was reduced. Thus, shooters looking to keep their rifle report to a minimum should not reduce the barrel length at all. Shooters who don't mind an increased report should proceed with caution, as the report pertaining to the final barrel lengths tested produced an intimidating report. Report and muzzle blast variations appear to be directly related, as the muzzle blast was also shown to increase with decreases in barrel length. Shooters who want to keep their muzzle blast minimized should not decrease the barrel length. Again, shooters who don't particularly mind an increased muzzle blast should proceed with caution, particularly of the muzzle blasts pertaining to the final barrel lengths tested, as they were quite tremendous in magnitude.

Sadly, no implications could be made to the precision characteristics (ultimately accuracy potential) of the Mosin-Nagant rifle. This is not to say there is no variation in the precision of the rifle as the barrel length is reduced, but rather to state that this specific experiment cannot confirm any variations for the greater or worse. It may be stated, however, that the rifle's precision wasn't degraded to such a negative effect that the rifle was no longer suitable for 100 yard target shooting.

REFERENCES:

[1] Rinker, Robert A. Understanding Firearm Ballistics: Basic to Advanced Ballistics : Simplified, Illustrated, and Explained. 6th ed. Clarksville, IN: Mulberry House Pub., 2005. Page-11. Print.

[2] Rinker, Robert A. Understanding Firearm Ballistics: Basic to Advanced Ballistics : Simplified, Illustrated, and Explained. 6th ed. Clarksville, IN: Mulberry House Pub., 2005. Page-327. Print.

[3] Rinker, Robert A. Understanding Firearm Ballistics: Basic to Advanced Ballistics : Simplified, Illustrated, and Explained. 6th ed. Clarksville, IN: Mulberry House Pub., 2005. Page-53. Print.

[4] Große Perdekamp, M., B. Vennemann, B. Kneubuehl, M. Uhl, M. Treier, R. Braunwarth, and S. Pollak. "Effect of Shortening the Barrel in Contact Shots from Rifles and Shotguns." *International Journal of Legal Medicine* 122.1 (2008): Pages 81-85. *SpringerLink*. Web. <http://dx.doi.org/10.1007/s00414-007-0161-y>.

[5,6] Plaster, John L. The Ultimate Sniper: an Advanced Training Manual for Military and Police Snipers. 2nd ed. Boulder, CO: Paladin, 2006. Page-40. Print.

[7] Gebhardt, James F. The Official Soviet Mosin-Nagant Rifle Manual: Operating Instructions for the Model 1891/30 Rifle and Model 1938 and Model 1944 Carbines. Boulder, CO: Paladin, 2000. Page-53. Print.

[8] Kasper, James. "BALLISTICS BY THE INCH: THREE GUYS, TWO CHRONOMETERS AND 7000 ROUNDS OF AMMO." Concealed Carry Magazine Apr. 2009: Pages 24-27. Web. <http://www.ballisticsbytheinch.com/CCM_Apr09_BBTI.pdf>.

[9] Rinker, Robert A. Understanding Firearm Ballistics: Basic to Advanced Ballistics : Simplified, Illustrated, and Explained. 6th ed. Clarksville, IN: Mulberry House Pub., 2005. Page-148. Print.

[10] Rinker, Robert A. Understanding Firearm Ballistics: Basic to Advanced Ballistics : Simplified, Illustrated, and Explained. 6th ed. Clarksville, IN: Mulberry House Pub., 2005. Page-155. Print.

[11] Plaster, John L. The Ultimate Sniper: an Advanced Training Manual for Military and Police Snipers. 2nd ed. Boulder, CO: Paladin, 2006. Page-477. Print.

[12] Plaster, John L. The Ultimate Sniper: an Advanced Training Manual for Military and Police Snipers. 2nd ed. Boulder, CO: Paladin, 2006. Page-39. Print.

[13] Kaw, Autar K., E. Eric. Kalu, and Glen Besterfield. Numerical Methods with Applications. Morrisville, NC: Lulu Enterprises, 2009. Page-357. Print.

[14] Kasper, Jim, Jim Downey, Steve Meyer, and Keith Kimball. Ballistics by the Inch. Coeurbois Graphic Design. Web. May 2011. <http://www.ballisticsbytheinch.com/>.

[15] Plaster, John L. The Ultimate Sniper: an Advanced Training Manual for Military and Police Snipers. 2nd ed. Boulder, CO: Paladin, 2006. Page-145. Print.

ACKNOWLEDGEMENTS:

I would like to thank and acknowledge everyone who has helped in making this experiment possible. My Parents: ***Roswell and Bobbie Clark***, whom helped to provide a testing location and aided in purchasing tools and equipment, they have always lent a helping hand and support. Thesis Mentor: ***Dr. Stuart Wilkinson***, who was responsible for agreeing to work with me on this sensitive subject, as well as guiding me through it. Thesis Committee Member: ***Dr. Michael Stokes***, who was also responsible in agreeing to work with me, and provided innovative ways of sighting the rifle to the target. Dean of the University of South Florida Honors College: ***Dr. Stuart Silverman***, who ultimately allowed a thesis of such nature, and was so very flexible in his help. I must note that is isn't common to find Deans and Professors with the backbone to support such experimental testing, especially in light of today's sensitive University views, and I thank them for their willingness to support my experiment involving firearms. ***Ken Norberg*** of Rock Solid Industries, who was kind enough to provide one of his scope mounts for a reduced cost, as well as providing tips towards exploiting the highest accuracy from the Mosin Nagant rifle. ***Razi Ullah***, a friend and peer also studying at the University of South Florida, Razi was responsible for all of the machining and installation work pertaining to the scope mount and scope installation on the experimental rifle previous to testing. Lastly I would like to acknowledge the ***United States of America***, for I'm sure there are others who would like to conduct similar testing but are barred from the right to bear arms in their respective countries. If it weren't for the Constitution and the preservation of our 2nd Amendment rights, this testing would have never taken place.